

**Validation of a simple clinical
formula for predicting birth weight
in women who are in labour at term**

**M Med Dissertation
Obstetrics and Gynaecology**

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DECLARATION

I, Karabo Juliet Tlale, declare that this research project is my own work with supervision from Professor E. Buchmann. It is being submitted in partial fulfillment for the Degree of Masters in Medicine (M Med) in Obstetrics and Gynaecology.

Dr K J Tlale

Date: 23 November 2011

University of Witwatersrand

DEDICATION

I dedicate my work to my son, Bokang . He is my joy and pride.

PUBLICATIONS (ANNEXURE 4)

Buchmann E, Tlale K. A simple clinical formula for predicting fetal weight in labour at term – derivation and validation. S Afr Med J 2009,99:457-60.

This work was published as part of validation for Prof E. Buchmann's work done at Chris Hani Baragwath Hospital.

PRESENTATIONS ARISING FROM THIS STUDY

- 1. Inter departmental Research day (Wits, Pretoria, MEDUNSA), November 2007 – Midrand, Johannesburg.**
Won Elsje Boes memorial prize for best Obstetric paper by a junior member of staff.
- 2. National Registrar day, August 2008 – Groote Schuur, Cape Town.**
- 3. Priorities in Perinatal Care in Southern Africa (28th annual conference), March 2009 – Champagne Sports Resort, KwaZulu Natal.**

ABSTRACT

Background

Estimation of fetal weight during labour at term is frequently done to decide if there is a risk of cephalopelvic disproportion or shoulder dystocia. Estimation of fetal weight by clinical palpation has been shown to be as good as ultrasound in labour at term, giving estimates that are correct to within 10% of the birth weight in 60% to 70% of cases.

Symphysis-fundal height (SFH) measurement may offer an easier method of fetal weight estimation, but no simple formula is currently available. The objective of this study was to validate a formula calculated from unpublished work done at Chris Hani Baragwanath hospital, where birth weight in g = 100 (SFH in cm – 5) for term intrapartum measurements. In that study, the formula gave estimates correct to within 10% of the birth weight in 67% of cases.

Methods

This was a prospective cross-sectional study done on women at term with singleton live cephalic presentations at the Charlotte Maxeke Johannesburg Academic Hospital and Chris Hani Baragwanath Hospital. All participants were in the active phase of the first stage of labour. The author performed abdominal palpation, and measured SFH twice, taking the average of the two measurements as the SFH. Maternal heights, weights, membrane status and level of the head were also recorded. The SFH measurements were transformed into estimated birth weights using the formula, and these were compared with the actual birth weights.

Results

The researcher assessed 294 women, 289 of them being black African. The mean birth weight was 3221 g and the mean SFH was 37 cm, which equated to a mean estimated birth weight, using the formula, of 3200 g. Simple linear regression between SFH and birth weight gave a correlation coefficient (r) of 0.56. The mean percentage error in fetal weight estimation using the formula was 8.7%. Sixty-five per cent of estimations were found to fall within 10% of the actual birth weight. Fetal weight estimates were best (mean percentage error 6.8%) in the birth weight range of 3000 g to 3499 g, and worst at the extremes of term birth weight.

Conclusion

The birth weight formula was validated in this study, giving very similar results to those found in the original research that described the formula. The formula may be applied by clinicians in environments that serve populations similar to those that participated in this study.

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INTRODUCTION AND LITERATURE REVIEW

Introduction

An accurate pre-delivery assessment and estimation of fetal weight is important in many obstetric situations.¹ Identification of the fetus at risk still represents one of the main difficulties in modern obstetrics, in spite of the availability of a wide range of clinical, biochemical and ultrasonographic techniques. Clinical decisions during the management of labour regarding augmentation or mode of delivery rely partially on estimation of the fetal weight. This may apply where there is poor progress in labour and transfer of the patient is needed, or labour augmentation is being considered, or where fetal macrosomia may be suspected. In the latter situation, this is related to risk for shoulder dystocia. Intrapartum clinical estimation of fetal weight at term (but not preterm) has been shown to be superior or equal to ultrasonographic assessment in a number of studies.²⁻⁶ All of these studies have relied on experienced clinicians' clinical fetal weight estimations and not on specific measurements. No simple and easily applied formula has yet been suggested to transform an external maternal measurement into an estimated fetal weight.

Literature review

External measurements including symphysis-fundal height

Numerous studies have been done to establish methods for clinical fetal weight estimation. External measurements of the mother provide an attractive means for determining fetal size. The first report of external measurements to predict birth weight was estimation of fetal weight according to the volume of the uterus using external and trans-rectal measurement of the different axes of the uterus by Poulos and Langstadt,⁷

who achieved an accuracy within around 250 g in 69% of estimations, with a correlation co-efficient (r) of 0.62 to 0.70. Poulos and Langstadt based their estimations on two theories. The first was the fundamental physical law stating that for a given homogeneous mass, the weight of the mass (W) is directly proportional to its volume (V), where the density (D) is constant ($W = DV$). In applying this to the birth weight of an infant and the volume of a uterus, it is obvious that the volume of the uterus is not accurately known, and certain assumptions must be made. This brought about the second theory on the theoretical volume of the uterus. The volume of the uterus was assumed to be either a sphere, or an ellipsoid (an ellipse rotated around its long axis). Based on these considerations, Poulos and Langstadt suggested a fetal weight formula of: birth weight (g) = $1870 + 0.11D^3 \pm 250$, with D being the mean of the transverse and longitudinal uterine diameters in cm. This provided the estimates described above. All subsequent measurement formulas depend to a greater or lesser extent on Poulos and Langstadt's mathematical assumptions.

The use of symphysis fundal height (SFH) measurement was first described by Johnson and Toshach,⁸ who claimed an accuracy within 240 g in 50.5% of 200 women examined. They found that fetal weight estimation was affected also by head descent and maternal obesity, and suggested the birth weight formula, using the imperial system:

Birth weight = 7 pounds, 8 ounces + $[(M + S - O - 34) \times (5.52 \text{ ounces})]$ where:

M = height of fundus in cm

S = station, subtracting 1 cm for minus stations, adding 1 cm for plus stations

O = obesity, subtracting 1 cm for women weighing over 200 pounds (91 kg).

In a subsequent study, Johnson⁹ presented a simplified formula that took into account the more modern metric system. For a fetus with a non-engaged head, it was suggested that:

Birth weight in g = (SFH measurement in cm – 13) × (155). Despite claims of reasonable accuracy, these authors did not validate their findings in repeat studies.

A South African study, done by Bothner et al,¹⁰ in the teaching hospitals in Johannesburg, showed good correlation between intrapartum SFH measurement and birth weight (r = 0.56). Their equation was:

Birth weight = (SFH – fifths – 20) × (300).

The findings of their work done in established labour, at gestational age ranges of 27 - 44 weeks by dates and 25 – 42 weeks by ultrasound, suggested that the level of the fetal head and status of membranes, either intact or ruptured, might affect SFH measurement. However, they concluded that SFH measurement for fetal weight estimation was not clinically useful using their formula. Subsequent to that, Jeffery et al¹¹ from Pretoria reported even better correlation (r=0.74) in a similar study. However, neither study could suggest a simple formula to translate SFH measurement into birth weight. Other Southern African studies on the subject have come from Mozambique, Tanzania and the Comores. The Mozambican study focused on identification of low birth weight babies, and did not provide any equation or formula.¹² The Tanzanian researchers found good correlation

($r=0.64$) with birth weight and SFH but the predictive value of SFH was mainly in its ability to identify low birth weight infants. They found that SF measurement on admission to labour ward of 29 cm or less predicted a birth weight of less than 2000 g. However, an SFH measurement greater than 38 cm was deemed to be significantly predictive for a large baby (over 4000 g) or a twin pregnancy.¹³ The Comorian study also found good correlation ($r=0.59$) but again concentrated on prediction of low birth weight infants.¹⁴ To the best of the author's knowledge, no study, from South Africa or elsewhere, has been able to suggest a simple formula for birth weight based on SFH. Prediction of large infants has been somewhat neglected or found to be difficult in the studies mentioned. Some authors have felt that SFH measurement is not sensitive or specific enough for practical use.^{10,15,16}

The accuracy and reliability of SFH measurement has been questioned. Besides artefactual problems such as maternal obesity, level of fetal head, and membrane status, a full bladder may also increase the SFH artificially especially at gestational age of 16 – 42 weeks.¹⁷ Agreement between two observers was found to be poor in a carefully controlled study done in the United Kingdom.¹⁸ The researchers found that the SFH measured independently by two clinicians in 39 women differed by 2 cm or more in 19 participants. The method therefore needs to be properly standardized. Fairly clear descriptions of SFH measurement have thus been provided by Westin,¹⁹ Theron²⁰ and Bothner.¹⁰ Based on these authors' suggestions, the most reliable method would be measurement in a supine position with an empty bladder, between uterine contractions. The highest point on the fundus should be determined by placing a single finger

transversely over that point, not necessarily in the midline, and marking this with a pen. The finger should be depressed only gently, just enough to determine the upper limit of the uterine fundus. No attempt should be made to correct the fetal lie to be perfectly longitudinal. The measurement is then taken with a non-flexible tape measure from the skin directly above the upper edge of the pubic symphysis to the marked point at the fundal height. Two measurements should ideally be made and the average of these taken as the SFH.

Historically, four other general approaches to birth weight prediction have been attempted. These will be discussed briefly below to provide context to SFH measurement for birth weight prediction.

Abdominal palpation

Fetal weight estimates may be based upon abdominal palpation, using Leopold's maneuvers, to manually estimate fetal dimensions. One of the earliest investigators of this method was Loeffler,²¹ who reported on simple palpation of the abdomen and uterus in a study on 585 patients who were in labour. In that series, 79.9% of estimates were within one pound (454 g) of birth weight. Palpation estimates by experienced practitioners during labour have given fetal weight estimations within 10% of the birth weight in 55% to 72% of palpations.^{2-6,22-25} Nahum²⁶ undertook a study in which he assessed whether it was still worth teaching Leopold's maneuvers to medical students and house staff for the purpose of estimating term fetal weight, and concluded that obstetric medical staff made more accurate predictions of term fetal weight using Leopold's maneuvers than students

and that this could have been due to the increased experience in using tactile techniques. He stated that Leopold's maneuvers are a useful method of estimating fetal weight and should continue being taught to both students and house staff. A consistent finding in the quoted studies on clinical fetal weight estimation has been a tendency to inaccuracy at extremes of weight, such as with preterm, growth-impaired or macrosomic fetuses.

Ultrasonography

In-utero fetal biometric assessment made by obstetric ultrasonography use best-fit algorithms to make birth weight predictions.²⁷ This provides an attractive 'objective' method of estimating birth weight. Willocks and colleagues²⁸ were among the first to report their experience with ultrasound fetal weight estimation, and commented that clinical estimation of fetal weight is little more than guess work because of the influence of factors such as abdominal wall thickness, uterine tension, volume of amniotic fluid, and position of the fetus in utero. It was claimed that in two thirds of cases fetal weight could be estimated to within about one pound using ultrasound. A large number of fetal weight prediction formulae have since been suggested based on fetal biometry including head biparietal diameter (BPD), head circumference (HC), femur length (FL) and abdominal measurements. A study was done by Shamley and Landon²³ to evaluate prospectively four published equations by Shepard et al,²⁹ Hadlock et al,³⁰ Rose and McCallum,³¹ and Sabbagha et al,³² as well as clinical estimation for accuracy in determining fetal weight in labour. The equations are known to use the following parameters:

- a) Hadlock et al - FL and abdominal circumference (AC)

- b) Shepard et al - BPD and AC
- c) Rose and McCallum - FL and abdominal diameter
- d) Sabbagha et al – a set of equations that use gestational age to account for fetal size, dividing the fetuses into three groups according to AC :
 - SGA (small for gestational age)
 - AGA (appropriate for gestational age) or
 - LGA (large for gestational age)

The Hadlock and Shepard equations both had a lower percentage of error than the Sabbagha formula (6.1% and 6.2% respectively, versus 7.8% ; $P < 0.007$). For all four equations, 70-79% of fetal weight predictions were within 10% of actual birth weight. The Shepard formula, however, has limited application in labour because head descent obscures the biparietal diameter which is essential to the fetal weight calculation. The conclusion from this study was that using any of the four standard equations or clinical examination, accurate estimation of fetal weight could be achieved for patients in labour, even in the presence of ruptured membranes. The accuracy of these ultrasound estimations presented here was not found in a number of other studies comparing simple palpation estimates with ultrasound based predictions. In these comparisons, the percentage of predictions within 10% of the birth weight for ultrasound estimation ranged from 39% to 69%.^{2-6,23-25} While ultrasound fetal weight estimation may not appear significantly better than clinical methods, a recent comparison by Peregrine et al has shown that estimation by ultrasound immediately before labor was more accurate than

clinical estimation for low and high birth weight babies, where clinical estimates are known to be relatively inaccurate.³³

A study by Yoni et al³⁴ looked at the effect of oligohydramnios on intrapartum estimation of fetal weight. The conclusion was that in term patients, intrapartum sonographic prediction of birth weight in the presence of reduced amniotic fluid volume offered no advantage over estimated fetal weight obtained by abdominal palpation. However, the presence of oligohydramnios significantly reduced the accuracy of intrapartum clinical as well as sonographic fetal weight estimations. Therefore it was suggested that intrapartum fetal weight estimation be obtained prior to artificial rupture of membranes.

Since the Hadlock equation does not rely on BPD measurements, it appears to be both the most accurate and clinically useful method for predicting fetal weight for patients in labour at term. Although the validity and reproducibility of these formulas has been documented in clinical practice with a reported systematic error of 10% or less relative to the actual birth weight, it is well recognized that various fetal factors may influence the accuracy of fetal weight estimations. However, there are few reports that document the effect of certain maternal characteristics, specifically maternal size and obesity, on the ability to obtain ultrasonographic fetal biometric measurements and consequently calculate reliable fetal weights.

Newer technologies may be able to provide better fetal weight estimation. Three-dimensional (3-D) sonography potentially allows superior fetal weight estimation by

including soft tissue volume of the fetal thigh, upper arm and abdomen.^{35,36} Its advantage over conventional two-dimensional ultrasound is that reproducible circumference and volumetric measurements become feasible by simultaneous visualization of three orthogonal fetal limb sections. However, the disadvantage is that 3-D sonography is a more time consuming process, requires technically advanced and expensive equipment, and special operator training and skills which may also be more difficult to apply during labour. It thus seems unreasonable to abandon the 2D ultrasound imaging for fetal weight estimation.³⁷

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A promising new development is fetal weight estimation by echo-planer magnetic resonance imaging (MRI). Its advantages compared with other imaging techniques include the ability to obtain multiplanar acquisitions and therefore theoretically improved resolution. Although it is feasible to calculate MRI fetal weight in sagittal, coronal, or axial planes, the recommended plane of imaging, slice of thickness, and associated number of acquisitions that most accurately determine term fetal weight had not yet been established or published at the time when Hassibi et al presented their findings in 2004.³⁸ They sought to determine whether there are differences in fetal weight calculation based on plane of imaging or thickness by comparing sagittal 5 mm, 3 mm, and axial 8 mm MRI acquisitions with term birth weight and sonography fetal weight calculations. Their goal was to help establish an optimal, practical protocol for fetal MRI in the prediction of fetal weight in the term infant. Calculated weights from a 90-sec single-shot fast spin-echo sequence MRI acquisition with 8mm thick slices in the axial plane at term were found to be better than sonographic estimates. The problem with these methods, in

addition to their expense, is again their impracticality for obtaining measurements during labour.

Quantitative assessment of maternal characteristics

A number of researchers have described quantitative assessment of measurable maternal and pregnancy specific characteristics and risk factors such as obesity, maternal pre-pregnancy weight, gestational weight gain, parity, smoking, diabetes and altitude of residence, in addition to fetal characteristics, such as fetal gender and the length of gestation. Knowledge of the influence of these factors may contribute to birth weight estimation. Work done by Wikstrom et al³⁹ showed positive effects on birth weight for pre-pregnancy weight, gestational weight increase, gestational duration, and high birth weight of a previous infant (greater than 4000 g). Smoking was found to have a negative effect by reducing birth weight. Height, parity and age did not have a significant effect. All significant variables had a strong association with birth weight ($p < 0.001$). Other examples are from work done in the United States of America.⁴⁰ Such formulae are generally only reliable in the communities in which they have been researched, and have not found favour in general obstetric practice.

Maternal estimates of fetal weight

An intriguing method of fetal weight estimation is asking the pregnant woman. Chauhan described in 1992 how 106 parous women gave better fetal weight estimations (69% within 10% of actual birth weight) than their doctors (66%).³ Herrero and colleagues⁴¹ made similar findings. It is thought that parous women are able, if they know their

previous babies' birth weights, to determine the approximate size of their current pregnancies. However, maternal estimates have not been seriously considered by obstetric clinicians in practice.

Problem statement

A simple formula for birth weight calculation based on symphysis-fundal height

Estimation of fetal weight may be required in situations where ultrasound facilities are not available. Even if available, such measurements may be inaccurate during labour and at term, especially if the membranes are ruptured and the presenting part is engaged in the pelvis.¹⁰ Clinical palpation of the abdomen in estimating fetal weight requires considerable experience and training. SFH measurement with a tape - measure seems a simple clinical method because it is cheap, readily available, non-invasive and acceptable to patients.¹⁰ It is a reproducible technique that is easily learned. Yet it still presents problems with conversion of a measurement to fetal weight estimate. As stated earlier, no simple reliable SFH based formula has been found to be useful in the estimation of birth weight during labour.

A prediction formula for birth weight

Recent unpublished observations⁴² in a study of term pregnancies in the active phase of labour at Chris Hani Baragwanath Hospital have suggested that birth weight can be deduced from SFH by subtracting 5 from a measured SFH in cm and multiplying by 100 to get birth weight in grams, or as a formula:

Birth weight in g = 100 (SFH in cm – 5).

Such a formula can be remembered easily by midwives and doctors as subtracting 5 from the SFH and predicting a birth weight, for example an SFH of 34 cm gives a fetal weight of 2900 g, or an SFH of 40 cm gives a fetal weight of 3500 g.

The study which suggested this formula was a prospective cross-sectional study of 504 term pregnancies in which a number of intrapartum clinical observations were evaluated, including symphysis-fundal measurement. In each participant, the SFH was compared with the researcher's and attending clinicians' clinical estimation fetal weight with respect to the birth weight found after delivery.

From a regression line for birth weights versus SFH measurements, the above formula was determined from approximation of the obtained regression equation. Using the formula, 67% of birth weights were predicted to within 10% of the birth weight ($r=0.64$). This was as good a prediction as that obtained from clinical palpation by the researcher (67%; $r=0.62$), and better than that obtained by the attending clinicians (56%; $r=0.45$). In addition, the researcher in that study found a 40 cm SFH cut-off to be useful in the prediction of large infants (4000 g and above), with a sensitivity of 82% and a specificity of 80%. The negative predictive value was possibly the most useful, being 99%. This suggested that an SFH of less than 40 cm gave 99% assurance that the birth weight would be less than 4000 g.

Justification for the study

The formula mentioned above therefore offered the possibility of a simple calculation for estimated fetal weight for use by midwives and doctors in South Africa. For this to gain favour, the formula required validation in a repeat experiment by a different observer or different observers using a similar methodology. An affirmative answer to that question would offer a simple formula for intrapartum prediction of birth weight at term in a South African community.

OBJECTIVES

This study was undertaken with one primary and two secondary objectives:

- The primary objective: to validate the formula that
birth weight in g = 100 (SFH in cm – 5). If this formula gave $\geq 60\%$ of predictions within 10% of the actual birth weight, it would be considered validated.
- Secondary objective: to identify clinical variables that influenced the prediction of birth weight by SFH measurement.
- Additional secondary objective: to investigate the value of a 40 cm SFH cut-off in the prediction of the large fetus (4000 g and above)

MATERIALS AND METHODS

Study design and setting

This was a prospective cross-sectional study performed from May to September 2007. Approval for the study was given by the Committee for Research on Human Subjects of the University of the Witwatersrand (Annexure 1). The study population was women in the active phase of labour (cervix 3 cm or more dilated and fully effaced). Inclusion criteria were age 18 and above, booked for antenatal care with known height and weight for body mass index (BMI) calculation, term (37 weeks' gestation or more) singleton pregnancy, live fetus, with a longitudinal lie and cephalic presentation. The exclusion criteria were known severe fetal congenital anomalies, polyhydramnios (amniotic fluid index greater than 24 cm or clinically assessed), known fibroid uterus or maternal diabetes mellitus. The labour wards of the Charlotte Maxeke Johannesburg Academic and Chris Hani Baragwanath Hospitals were chosen as sites for this study. Both are referral units, but still manage a substantial number of women that fit the inclusion and exclusion criteria for the study. The majority of pregnant women treated in these hospitals are black African.

Sampling

A sample size calculation suggested that 340 participants would be needed to give a precision of 5% around an observed percentage of estimated fetal weights correct to within 10% of the birth weight. For example, such a sample size would give a 95% confidence interval of 55% to 65% if the observed percentage was 60%. Women were

sampled in a consecutive manner on days when the author could spend time doing these measurements in the labour units of the two hospitals.

Data collection

Women who met the criteria were recruited to participate in the study. Initially, verbal consent for inclusion in the study was obtained. The signed consent form to use the study data was only completed after delivery (Annexure 2). During admission and while awaiting delivery during progression of labour, the author recorded baseline data as shown on the datasheet (Annexure 3). This included ethnic group, age, parity, smoking, HIV status, height and weight at first antenatal visit and the derived body mass index, gestational age, membrane status (intact or ruptured) and the cervical dilatation at the most recent vaginal assessment by the attending clinicians. These were the variables to be assessed as influential or not in the study.

As soon as it was convenient, the author performed abdominal examination between contractions with the woman in the supine position. Cephalic presentation was confirmed and the level of the head in fifths was determined, using the method of Crichton.⁴³ A head that is two-fifths or less palpable above the brim is considered to be engaged in the pelvis. A head that is three-fifths or more palpable is not engaged. Women with palpably full bladders were asked to void before measurements were taken. A note was made as to whether the membranes had ruptured or not at that time. The SFH was measured twice at an interval of 5 to 20 minutes following the method described by Theron in the Maternal Care Manual of the Perinatal Education Programme.²⁰ This was achieved by using gentle downward pressure with the right index finger to identify the highest point of the uterus,

not necessarily in the midline, then taking measurements from the upper border of the pubic symphysis to the highest point of the uterus. The highest point on the uterus was marked with a pen only on the second measurement. A soft non-flexible tape was used for measuring, and the mean of the two measurements was taken as the SFH. All measurements were performed by the author. To standardize measurements, the author was trained in correct measurement of SFH before starting the study. This was done by her supervisor, who is experienced in SFH measurement. After delivery, records were made of the mode of delivery and the actual infant's weight. The birth weights were measured shortly after birth on the hospital baby scales in the labour ward nurseries by the attending midwives. The author made frequent checks during the study to ensure that the scales were correctly zeroed and calibrated. During the study it became apparent that the majority of women at Chris Hani Baragwanath Hospital did not have antenatal heights recorded. The author then measured these women's heights supine in the labour ward.

Data analysis

All data analysis was done on Microsoft Excel 2003 and Epi-Info 6 software. Descriptive statistics included calculations of means $\pm$ standard deviations, medians with ranges, and frequencies expressed as percentages with 95% confidence intervals. Simple linear regression was done to describe the association between fetal weight estimation using the formula described above, and the birth weight, using the correlation coefficient (r), and a scatter plot. The difference between a fetal weight estimate and the birth weight in each case was expressed as a percentage error, given as the difference divided by the birth

weight, multiplied by 100. Mean percentage errors were calculated for all participants and for selected subgroups. Differences in mean percentage errors between subgroups were examined using the Student's t-test, with $P < 0.05$ indicating statistical significance. Percentage errors were also grouped as being within 10%, 20% or 30% of the birth weight. The predictive ability of SFH in identification of large fetuses was presented using a two-by-two table, showing sensitivity, specificity, positive predictive value and negative predictive value.

RESULTS

The author measured and followed up 294 women and their infants. There were 195 participants from Charlotte Maxeke Johannesburg Academic Hospital and 99 from Chris Hani Baragwanath Hospital. All, except for four coloured and one white woman, were black African. The mean age was 26.6 ± 5.8 years. One hundred and eleven women (37.8%) were primiparous. The mean parity was 1.12, with a median of 1 and a range of 0 to 8. There were 10 smokers (3.4%). Out of 246 women tested for HIV, 63 (26.3%) had positive results. Weights and heights were not available for 16 women (5.4%). Weight and height data, as well as gestation and intrapartum details, mode of delivery and birth weight, are shown in Table 1. Thirty-seven women (12.5%) were at full cervical dilatation at the time of the author's measurements. It should be noted that in 92 women (31.3%), measurements were made more than two hours after the last clinician's vaginal assessment.

Table 1. Basic maternal anthropometric and intrapartum data for participant women; means $\pm$ standard deviations or number (%), (n=294).

Height (cm) (n=278)	159.8 ± 6.2
Weight (kg) (n=278)	73.9 ± 15.8
Body mass index (kg/m^2) (n=278)	29.2 ± 6.0
Gestation at delivery (weeks)	39.2 ± 1.4
Cervical dilatation before examination (cm)	5.5 ± 2.4
Membranes ruptured at time of measurement	152 (51.7%)
Level of head on abdominal palpation (fifths)	3.2 ± 1.2
Caesarean delivery	77 (26.2%)

Birth weight (g)	3221 $\pm$ 417
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Symphysis - fundal height measurement and birth weight

Symphysis-fundal height (SFH) measurements were taken twice and rounded to the nearest cm in 189 women (64.3%). The average of the two SFH measurements was recorded for each woman and the mean average SFH measurement for all participants was 37.0 ± 3.2 cm. Simple linear regression of birth weight revealed a correlation coefficient (r) of 0.56 (95% confidence interval 0.48-0.66); $P < 0.0001$). A scatter plot with regression line and equation is shown in Figure 1. The gradient of the regression line is 71.3 g/cm, suggesting that for every increase in SFH of 1 cm, the birth weight increases by 71.3 g. The prediction line suggested by the hypothesized formula is also shown. The formula gives a gradient of 100.0 g/cm.

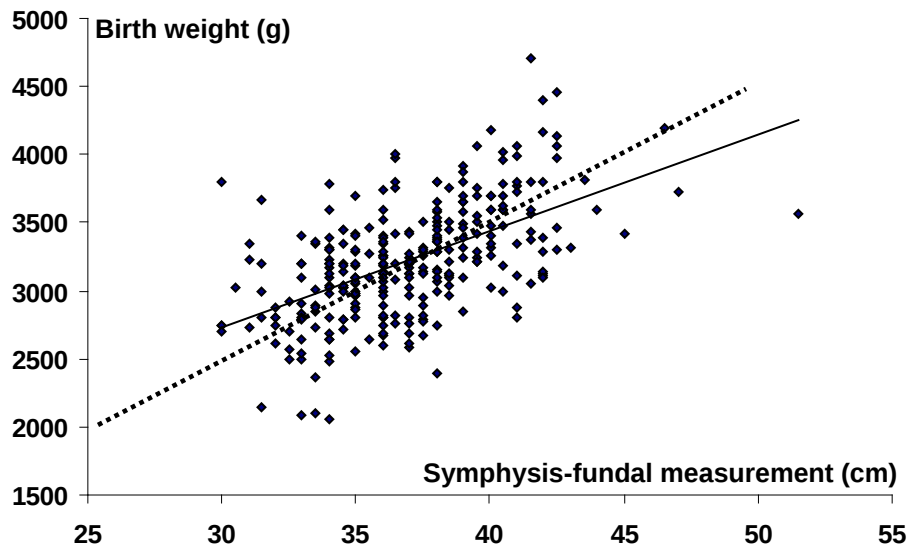


Figure 1. Scatter plot of birth weight and symphysis-fundal height measurement, with solid regression line (regression equation: $y = 585 + 71.3x$; $r = 0.56$ (95% confidence interval 0.48-0.66)). The dotted line indicates the birth weight prediction suggested by the hypothesized formula: birth weight = $100(\text{SFH} - 5)$

Variables that may influence SFH, birth weight and their correlation

The author investigated the influence of membrane rupture, head engagement, and body mass index (BMI) on SFH measurement and correlation of SFH with birth weight. The mean SFH was significantly lower in association with an engaged head (35.8 cm v. 37.3 cm; $P=0.001$). Women with membranes intact did not have significantly greater SFH than those with ruptured membranes. Head engagement and membrane status had no significant effect on the correlation coefficient. Women with a BMI of 30 kg/m² or more had significantly greater SFH measurements (38.4 cm v. 36.3 cm; $P<0.0001$) and gave birth to significantly larger infants (3363 g v. 3148 g; $P<0.0001$). For these women the correlation coefficient tended to be lower (0.49 v. 0.57) than for women with a BMI less than 30 kg/m². These findings are shown in more detail in Table 2.

Table 2. Influence of membrane status, engagement of the fetal head and body mass index (BMI) on symphysis-fundal height (SFH), birth weight, and correlation of SFH with birth weight (BW). r = correlation coefficient.

	N	r	95 % CI	Mean SFH (cm)	Mean BW (g)
Membranes: Intact	142	0.57	0.42-0.69	37.1	3245
Ruptured	152	0.58	0.42-0.69	36.8	3199
Head: Engaged	60	0.63	0.40-0.77	35.8*	3253
Not engaged	234	0.59	0.48-0.67	37.3*	3213
BMI: <30 kg/m ²	178	0.57	0.42-0.67	36.3†	3148‡
≥30 kg/m ²	100	0.49	0.22-0.65	38.4†	3363‡
(n=278)					

Student's t-test for differences in means: * $P<0.001$; † $P<0.0001$; ‡ $P<0.0001$.

Prediction of birth weight using the hypothesized formula

The value of the formula: birth weight in kg = 100 (SFH in cm – 5) was investigated by transforming each averaged SFH measurement to an estimated fetal weight (EFW), and comparing this with the actual birth weight. A percentage error was calculated for each estimation. Based on the formula, the mean EFW for the entire sample was 3200 ± 323 g. The mean percentage error for all estimations was 8.7 ± 7.2 . The mean percentage error was lowest for the 3000 to 3499 category of infants (6.8 ± 5.4) and highest at extremes of birth weight (Table 3).

Table 3. Mean percentage error in estimation of fetal weight using the formula: birth weight in kg = 100 (SFH in cm – 5). This is shown for birth weight categories from less than 2500g to cover 3999g, for all participants.

Birth weight category	N	Mean percentage error $\pm$ standard deviation
Less than 2500 g	7	30.0 ± 9.5
2500 – 2999 g	74	9.5 ± 6.8
3000 – 3499 g	145	6.8 ± 5.4
3500 – 3999 g	56	8.9 ± 6.8
Greater than 3999 g	12	13.4 ± 5.8
All infants	294	8.7 ± 7.2

Table 4 shows the distribution of percentage error divided into underestimated and overestimated fetal weights. One hundred and ninety-one estimations (65.0%; 95%

confidence interval 59.2 to 70.4%) were within 10% of the birth weight. Another 84 (28.3%) were 10% or more off, but fell within 20% of the birth weight. The greatest overestimation was 41.5%, where an SFH of 34 cm corresponded to an estimated fetal weight, using the formula, of 2900 g. The actual birth weight was 2050 g. The greatest underestimation was 27.8%, where a projected fetal weight of 2650 g (SFH 31.5 cm) was followed by delivery of an infant weighing 3670 g.

Table 4. Distribution of percentage error in estimation of fetal weight using the formula: birth weight in kg = 100 (SFH in cm – 5), grouped by over- and underestimation (n=294).

	Percentage error	N	Per cent
Overestimation	≥30.0	5	1.7
	20.0 – 29.9	8	2.7
	10.0 – 19.9	42	14.3
	<10	72	24.5
Exact estimate	0	6	2.0
Underestimation	<10	113	38.4
	10.0 – 19.9	42	14.3
	20.0 – 29.9	6	2.0

Prediction of above-average birth weight

The ability of a 40 cm SFH to identify above-average sized infants was investigated. An SFH of 40 cm or more was obtained in 60 participants. For these 60, the mean birth weight was 3602 ± 402 g. Forty-nine of the infants born to these mothers (81.7%) had

birth weights greater than 3221 g, the mean for all participants in the study. Of 12 infants with birth weights greater than 4000 g, 10 (83.3%) had SFH measurements greater than 40 cm. The sensitivity, specificity, positive predictive value and negative predictive value of a 40 cm SFH for a birth weight of 4000 g or more are shown in Table 5. The negative predictive value of an SFH measurement less than 40 cm for an infant lighter than 4000 g was 99.1%.

Table 5. Prediction of birth weight of 4000 g or more using an SFH measurement cut-off of 40 cm, showing sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV).

	Birth weight ≥4000 g	Birth weight <4000 g	Total
SFH ≥40 cm	10	50	60
SFH <40 cm	2	232	234
Total	12	282	294
Sensitivity = 83.3%, Specificity = 82.3%, PPV = 16.7%, NPV = 99.1%.			

DISCUSSION

Meaning of the results

This study validated the formula suggested by the earlier study in a similar obstetric population. The formula provided intrapartum prediction of birth weight at term in singleton live vertex presentations to within 10% of the birth weight in 65.0% of estimations. This is marginally less than, but satisfactorily similar to, the 67% found in the previous study.³⁹ The fact that the mean SFH was 37 cm and the mean birth weight was 3221 g alone gives credence to the suggested formula. The correlation coefficient ($r = 0.56$) provided good correlation of SFH with birth weight, the same as that of Bothner et al ($r=0.56$),¹⁰ but somewhat less than in the study by Jeffery et al ($r=0.74$).¹¹ The scatter plot with regression equation found the birth weight to increase by 71 g for each cm SFH. This is rather less than the 100 g per cm suggested by the formula. However, inspection of the scatter plot in Figure 1 shows that the two lines diverge most at the extremes of SFH measurement and birth weight, and almost coincide through much of the mid-range of measurements. From inspection of the scatter plot and the lines, the formula therefore would be expected to give reasonably good birth weight predictions in the SFH range of 32 to 42 cm.

Several variables were measured to determine their effect on the fetal weight estimation. The state of the membranes, whether ruptured or not, appeared to have no effect on the SFH or the correlation of SFH and birth weight. This has been found by several other authors.^{9-11,23} Head engagement also had no effect on the correlation coefficient but did influence the SFH measurement, with a mean reduction of about 1.5 cm when the head

was engaged as opposed to unengaged. Bothner et al¹⁰ found that engagement of the head was associated with a reduction in SFH measurements on average of about 1 cm per fifth of head above the brim from four-fifths to one-fifth. It would therefore be most pragmatic to make fetal weight estimations based on SFH early in labour, before the head engages, to prevent interference of head descent in these estimations. An increased body mass index predictably resulted in greater SFH measurements and higher birth weights. The effect of the bladder, whether empty or full, was not measured in this study but, as stated earlier, the participants were asked to void before measurements were taken. According to Engstrom¹⁷ and Bothner,¹⁰ it is important to keep in mind the importance of making the SFH measurement with an empty bladder, to prevent overestimation of the fetal weight.

The 40 cm cut-off for macrosomic babies (birth weight of 4000 g and above) proved to be moderately useful. While the positive predictive value was poor at 17%, the negative predictive value of 99% provided a useful indicator. What can be said from the results is that if an SFH measurement is 40 cm or more, there is an 80% chance of the baby being born with an above-average weight; and if the SFH is less than 40 cm, there is a 99% chance that the birth weight will be less than 4000 g. Of course, this only applies in communities such as in South Africa, where macrosomia at birth is relatively uncommon (about 2.3% to 3.5%).^{44,45}

Limitations

There were a number of limitations to this study. Many participants (number not recorded) at Chris Hani Baragwanath Hospital did not have heights written on their antenatal cards and it was difficult to follow this up because most came from surrounding satellite clinics that refer to the hospital. To overcome this problem, the author had to take supine height measurements in the labour ward. Sixteen patients had neither heights nor weights written on their cards and their body mass indices could not be calculated. The antenatal weights were taken at varying gestational ages during the pregnancies, and the author was unable to verify the antenatal weights or heights from the referring clinics. Body mass index results must therefore be regarded as approximate.

The proposed sample size ($n=340$) was not achieved. This was the result of limited time available to the researcher, and exclusion of seven women because of failure of labour ward staff to record birth weights. The well-publicized South African public servants' strike that occurred in June 2007 also reduced labour ward admission numbers at Johannesburg Hospital, and rendered Chris Hani Baragwanath Hospital unsafe. However, the final sample size of 294 still gave a reasonable 95% confidence interval of about 6% around the observed 65.0% accuracy rate for the formula.

Since the study did not include babies of less than 37 weeks gestational age, no conclusion can be made about fetal weight prediction for preterm babies or for those in the lower range of birth weight at term. Inclusion of pregnancies at less than 37 weeks might have given more insight into birth weight prediction for birth weights around and

less than 2500 g. Useful information on smaller babies is available from Jeffery et al,¹¹ who showed that SFH of less than or equal to 29cm is a good predictor of birth weight less than 2000 g.

It may be said that the second SFH measurements in the women could have been biased by the author's knowledge of the first. A blank tape-measure without cm marks would have prevented this, but this was not used. SFH measurement by multiple observers, not a single one as in this study, may have given results more typical of what is found in clinical practice. However, for research purposes, the use of single well trained practitioner is desirable to give a best-case scenario.

CONCLUSION

The formula: **birth weight in g = 100 (SFH in cm – 5)** was successfully validated in this study. For intrapartum estimation of birth weight at term in vertex singleton live babies, health workers may expect the formula to give birth weight estimations correct to within 10% of the actual birth weight in 60 to 70% of cases. This may be applied in institutions that have obstetric populations similar to those at Chris Hani Baragwanath Maternity Hospital. It should be noted that SFH measurement is adjunctive to, and does not replace, clinical palpation. Assessment of lie, presentation, number of fetuses and liquor volume remain essential clinical skills to be employed in the care of all women in labour.

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Dr JK Tlale
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Dear Dr Tlale

Master of Medicine in the specialty of Obstetrics and Gynaecology: Approval of Title

We have pleasure in advising that your proposal entitled "*Validation of a simple clinical formula for predicting birthweight in women who are in labour at term*" has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

A handwritten signature in black ink, appearing to read 'Sandra Benn', with a horizontal line underneath.

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

PATIENT INFORMATION LEAFLET AND INFORMED CONSENT

Validation of a simple clinical formula for predicting birth weight in women who are in labour at term

Study doctor: Dr K Tlale

Participant study number

Good day.

My name is Dr Karabo Tlale. I am a doctor who is training to be a specialist in Obstetrics and Gynaecology. As part of my training I am doing a research project to achieve a master's degree (M Med) with the University of the Witwatersrand. I am inviting you to take part in this project. This form has information to help you decide if you want to participate. Take your time, read this form carefully, and feel free to ask me or any of the staff to assist you with explanations.

What is this project about?

The purpose of this research is to find out if we can use the measurement of your womb to work out the birth weight of your baby. Research done at other hospitals has shown that if you are nine months pregnant and in labour, this might be the best way to know in advance if the baby will be big or small. This method may be even better than sonar. I want to test this measurement to see how accurate it is. I also want to see if the accuracy is affected by other things like whether you are tall or short, overweight or underweight, or how your baby is lying in your womb.

Why have I been chosen to participate in this project?

You have been chosen because you are nine months pregnant and in labour, exactly the type of woman where the measurement can be useful.

What exactly will be done with me?

I want to measure the size of the womb on your tummy with a measuring tape. This is done with you lying straight and on your back. I shall do this twice. The first time I will use a blank tape, and about 10 minutes later I will make a mark on your tummy with a pen and use a tape with measurements on it. I will also feel if the baby's head is facing downwards, and how much it has gone down. I will then look in your hospital file to find out things about you, such as your height and weight, your age, how many babies you have had, and if there are any problems with the pregnancy or labour. Later today or tomorrow, I will come back to the labour ward and find out when and how you delivered, and how much the baby weighed when it was born.

How do I gain from participating in this project?

You do not gain directly. What I am doing will not affect the way you are treated. This is a research project for improving the knowledge of health workers. The measurements that I find will not be used for treating you, and will not be made known to the nurses and doctors who are responsible for your care. I can not give you any reward just because you agree to participate in this project.

Could there be any harm to me if I participate?

Lying on your back so that I can measure you and feel your baby's head will take less than two minutes and should not cause any harm to you. It will not be painful. I will not be examining you in the vagina, and I will not be taking any samples using needles.

Could the information obtained from my file end up in the wrong hands?

No. Everything I find out about you is strictly confidential. All the measurements and information will go onto a special form that will not have your name or hospital number on it. The form contains only a study number, and I will be the only person who knows that the study number is yours.

What will happen if I do not want to participate?

You are free to refuse to be in this project. This will not affect the way you are treated by the nurses and doctors here. Even if you sign this form to participate, and you change your mind later, you may withdraw from the project. That is your decision and I respect that.

Who can I speak to if I have any questions even after I leave the hospital?

If you have any problems or queries about this research, you may ask your doctor or nurse, or speak to me directly at 082 9613801. You may also call my research supervisor, Professor E Buchmann, at 011 9338155 or Dr M Mokhachane, of the Wits Human Research Ethics Committee at 011 9338000.

CONSENT

I hereby agree to participate in this project. Dr Tlale will measure my height, and take measurements on my tummy and will use information from my file. The forms she uses in this project will not include my name or my hospital number. I understand that I am not entitled to any gain or reward as a result of my participation. I also understand that I may withdraw my consent for participation at any time, even after I have signed this form.

Participant.....

Witness.....

Researcher.....

Time.....

Date.....

DATA SHEET

Study number _____ Date ____/____/____

Ethnic ____ BWCA=1-4

Age ____

Para ____

Smoker ____ 0=no, 1=yes

RVD ____ 0=neg, 1=pos

Height ____ cm

Weight ____ kg

BMI ____ . ____

Gest at booking ____

Gest at first US scan ____

Gest now ____ weeks

Cervix dilated ____ cm: Completed hours ago ____

Membranes ____ 0=intact, 1=ruptured

Examination:

Head above brim in fifths ____

SFH (1) ____ cm

SFH (2) ____ cm

Mean ____ . ____ cm

Mode of delivery ____ 1=VD, 2=CS

Hours from examination to delivery ____

Duration of active phase ____

(Unknown = 9 or 99 or 999 in all fields)



A simple clinical formula for predicting fetal weight in labour at term – derivation and validation

Eckhart Buchmann, Karabo Tlale

Objectives. To derive and validate a simple formula for birth weight based on symphysis-fundal height (SFH) measurement during labour, and to determine a useful SFH cut-off value for prediction of birth weight $\geq 4\,000$ g.

Methods. In a derivation study, SFH was measured in women at term in the active phase of labour. A simplified formula for birth weight was derived from a regression equation. The best cut-off SFH measurement was obtained for prediction of birth weight $\geq 4\,000$ g. After this, a similar study was done to validate these findings.

Results. In the derivation study ($N=504$), birth weight was predicted by the equation: birth weight in g = $301 + 78$ (SFH in cm). This was transformed to the simplified formula: birth weight in g = 100 [(SFH in cm) $- 5$]. Using this formula for the data set, 68.1% of birth weight estimates were correct to

within 10% of the birth weight. For prediction of birth weight $\geq 4\,000$ g, an SFH measurement of 40 cm had a sensitivity of 82% and a specificity of 80%. In the validation study ($N=294$), the derived simplified formula gave 65.0% of estimates correct to within 10% of the birth weight. The predictive values of the 40 cm SFH cut-off were similar to those in the derivation study.

Conclusion. The derived simplified formula was validated in the second study. The formula may be useful for intrapartum use in term pregnancies. A cut-off SFH measurement of 40 cm may identify labours at risk for cephalopelvic disproportion or shoulder dystocia.

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Clinicians frequently estimate fetal weight when examining women in labour at term. This may help in predicting cephalopelvic disproportion when labour progress is poor,¹ or give early warning of possible shoulder dystocia.² In experienced hands, intrapartum clinical estimates of birth weight for term infants are at least as good as ultrasound-based predictions, being correct to within 10% of the birth weight in 55–72% of estimations.^{3–10} A more objective estimate of fetal weight may be offered by measurement of symphysis-fundal height (SFH) using a tape measure.^{11–13} This requires minimal experience, relying only on identifying the upper edge of the pubic symphysis and the highest point on the uterus. However, there is no simple formula that converts SFH measurement into fetal weight. The Johnson formula is frequently quoted, where birth weight in g = (SFH in cm $- 13$) $\times 155$, with further adjustments based on maternal obesity and engagement of the fetal head.¹² A South African study found good correlation of intrapartum SFH measurement with birth weight ($r=0.56$), and derived a regression equation, but the authors stated that the derived formula was 'not sufficiently accurate to be clinically useful'.¹⁴ A problem with fetal weight estimation is that all methods are least accurate at extremes of birth weight.^{15–17} Macrosomia (birth weight of 4 000 g and above) is notoriously

difficult to predict.^{2,18,19} Where a formula is inaccurate at the upper extreme of birth weight, the most useful tool may be a cut-off measure of SFH to assist prediction of macrosomia. This study was done to derive and validate a simple formula for birth weight based on SFH, and to determine a useful SFH cut-off value for prediction of fetal macrosomia (birth weight $\geq 4\,000$ g).

Methods

Derivation study

The derivation study was a prospective cross-sectional study undertaken from 2003 to 2005 at Chris Hani Baragwanath Maternity Hospital. The study was approved by the Human Research and Ethics Committee of the University of the Witwatersrand. This investigation of SFH measurement was part of a larger study, which was to evaluate clinical assessment in prediction of cephalopelvic disproportion. The methods have been described previously.^{20,21} The study population was women at 37 or more completed weeks of gestation in the active phase of labour (cervix fully effaced and at least 3 cm dilated) with singleton live fetuses and vertex presentations. Women with pre-existing or gestational diabetes mellitus were excluded. A consecutive sampling method was used on days that the researcher (EB) was available to collect data in the labour ward. All the researcher's measurements were done at the time of the routine labour ward rounds of the attending clinicians. Written informed consent was obtained from all participants.

The researcher palpated the woman's abdomen and estimated the level of head above the pelvic brim in fifths.²²

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The head was considered engaged if two-fifths or less was palpable above the brim. This was followed by marking the highest point on the uterine fundus, not necessarily in the midline, with a pen using a horizontal line.²³ Between uterine contractions, he identified the highest point on the fundus by gentle downward vertical pressure with the left index finger. The SFH was measured with a soft tape-measure from the superior edge of the symphysis pubis in the midline to the line identifying the highest point on the fundus, and recorded to the nearest 1 cm. Women with palpably full bladders were asked to void or were catheterised before proceeding with measurement. The state of the membranes was recorded as intact or ruptured, and cervical dilatation (in cm) was noted. After completing these observations, the researcher recorded race, age, parity, maternal height, maternal weight and gestation in weeks. Maternal weights were recorded from the first antenatal visit. Birth weights were measured on scales frequently calibrated by the researcher, and provided readings to the nearest 10 g.

Statistical analysis was performed using Microsoft Excel and Epi-Info 6 statistical software. Categorical data were presented as frequencies and percentages, and continuous data as means $\pm$ standard deviations (SD). Univariate linear regression analysis was done to study the relationship between SFH and birth weight. A scatter plot with regression line and equation was derived, with SFH as the independent variable and birth weight as the dependent variable. This was modified into a simplified formula for easy recall by clinicians, to offer estimations correct to within 10% of the birth weight in at least 60% of estimations, if possible. The influence of body mass index (BMI), membrane rupture and engagement of the fetal head was studied by comparing mean SFH measurements and birth weight, using Student's *t*-test with statistical significance defined as $p < 0.05$. To determine the most predictive cut-off measurement for macrosomia, a receiver-operating characteristic plot was made. A two-by-two contingency table was used to determine sensitivity, specificity, positive predictive value and negative predictive value of the SFH cut-off for macrosomia.

Validation study

The validation study was done using similar methods. Sample size calculation suggested that 340 participants would be needed to give a precision of 5% around an observed percentage of estimated fetal weights correct to within 10% of the birth weight. For example, such a sample size would give a 95% confidence interval (CI) of 55 - 65% if the observed percentage was 60%. The researcher who made measurements in the derivation study (EB) instructed a second researcher (KT) in recording SFH and collection of other data, as described above. Measurement was refined by measuring the SFH twice, 5 - 20 minutes apart, and recording the mean of the two measurements. This part of the study was done from July to September 2007 in the labour wards of Johannesburg Hospital

and Chris Hani Baragwanath Maternity Hospital. Approval for the validation study was given by the Human Research and Ethics Committee of the University of the Witwatersrand. If it were found that the simple formula could provide fetal weight estimates with 10% of the birth weight in over 60% of estimations in this validation, the formula would be acceptable for use in clinical practice.

Results

Derivation study

The researcher examined 504 women, 489 (97.0%) of black African ethnic origin. The mean age was 25.0 ± 5.8 years, and the mean gestation was 39.3 ± 1.6 weeks. Three hundred and twenty women (63.5%) were nulliparous. The mean maternal height was 157.4 ± 6.4 cm and the mean weight 69.2 ± 13.9 kg. The fetal head was engaged in 128 cases (25.4%), and the membranes were found to be ruptured in 263 (52.2%). The mean cervical dilatation at the time of examination was 5.9 ± 1.9 cm. The mean SFH was 37.0 ± 3.6 cm, with a range of 27 - 53 cm. The mean birth weight was $3\,190 \pm 436$ g, with a range of 1 880 - 4 890 g.

Univariate linear regression of SFH with birth weight gave a correlation coefficient of 0.64. The regression equation ($y = 301 + 78.0x$) suggests that for each cm increase in SFH, birth weight increased by 78 g (solid line in Fig. 1). Since a 78 g/cm increase could be rounded up to 100 g, this was adjusted, with minimal change to the regression line, to the simplified formula: birth weight in g = $100 \text{ (SFH in cm)} - 5$, giving an increase of 100 g in fetal weight for each cm SFH (dotted line in Fig. 1). It is evident from the regression line in the figure that the simplified formula prediction follows the statistical regression line most closely in the SFH range of 32 - 40 cm, equivalent to birth weights of 2 700 - 3 500 g. Using this formula to translate SFH measurements to birth weights, 343 (68.1%; 95% CI 63.8 - 72.1%) of estimates were accurate to within 10% of the birth weight. Accuracy within 20% of the birth weight was achieved in 470 estimations (93.3%; 95% CI 90.6 - 95.2%).

A BMI of 30 kg/m^2 or more was associated with higher mean SFH ($38.9 \text{ cm v. } 36.4 \text{ cm}$; $p < 0.0001$) and greater mean birth weight ($3\,298 \text{ g v. } 3\,155 \text{ g}$; $p = 0.0009$) than a BMI less than 30 kg/m^2 . The mean SFH was lower ($36.5 \text{ cm v. } 37.2 \text{ cm}$; $p = 0.03$) with an engaged fetal head than with an unengaged fetal head, with no difference in birth weight. Status of the membranes (ruptured or intact) was not associated with any difference in SFH or birth weight (Table I).

A receiver-operating characteristic plot (not shown) indicated that the 40 cm SFH cut-off provided the best predictive value for macrosomia. A cut-off of 41 cm was less sensitive (59%) but more specific (87%) and a cut-off of 39 cm less specific (70%) but more sensitive (91%). A 40 cm cut-off gave a sensitivity of 82% and a specificity of 80% for predicting a birth weight of

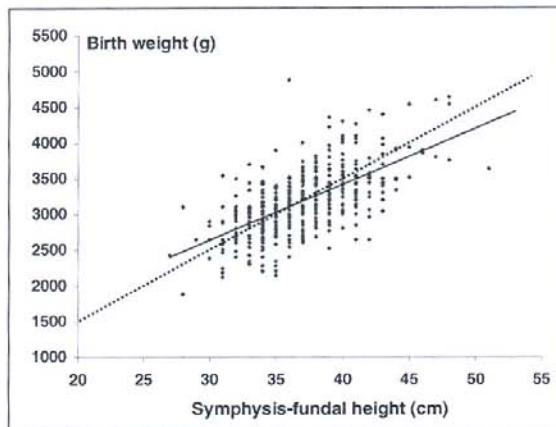


Fig. 1. Scatter plot for birth weight by symphysis-fundal measurement in the derivation study (N=504). The solid line represents the linear regression formula produced by the data ($y=301+78x$). The dotted line represents the simplified formula derived for clinical use (birth weight in g = 100 [(SFH in cm) - 5]).

4 000 g or more. The positive and negative predictive values for 40 cm were 16% and 99% respectively (Table II).

Validation study

There were 294 participants, of whom 289 (98.3%) were of black African ethnic origin. One hundred and ninety-five were investigated at Johannesburg Hospital and 99 at Chris Hani Baragwanath Maternity Hospital. Their mean age was 26.6 ± 5.8 years, 111 (37.8%) were primiparous, the mean gestational age at delivery was 39.2 ± 1.4 weeks, and the mean weight was 73.9 ± 15.8 kg. Membranes were ruptured at the time of measurement in 152 cases (51.7%) and the mean cervical dilatation was 5.5 ± 1.4 cm. The fetal head was engaged in 60 cases (20.4%) at the time of examination. The mean SFH, in each case using the average of two measurements, was 37.0 ± 3.3 cm. The mean birth weight was $3\,221 \pm 417$ g.

Table II. Two-by-two table for SFH measurement of 40 cm in the prediction of birth weight at a 4 000 g cut-off

	Birth weight		Total
	$\geq 4\,000$ g	$< 4\,000$ g	
SFH ≥ 40 cm	18	95	113
SFH < 40 cm	4	387	391
Total	22	482	504

Sensitivity = 82% (95% CI 59 - 94%); specificity = 80% (76 - 84%); positive predictive value = 16% (10 - 24%); negative predictive value = 99% (97 - 100%).

Univariate linear regression of SFH and birth weight revealed a correlation coefficient (r) of 0.56. The regression equation ($y=585+71.3x$) suggested an increase in birth weight of 71.3 g for each cm SFH. Using the derived simplified formula: birth weight in g = 100 [(SFH in cm) - 5], 191 estimations (65.0%; 95% CI 59.2 - 70.4%) were accurate within 10% of the birth weight. Accuracy within 20% of the birth weight was achieved in 275 estimations (93.5%; 95% CI 89.9 - 96.0%). A BMI of 30 kg/m² or above (N=100) was associated with greater mean SFH (38.4 cm v. 36.3 cm; $p<0.0001$) and greater mean birth weight (3 363 g v. 3 148 g; $p=0.0009$) than a BMI less than 30 kg/m² (N=178). The mean SFH was lower (35.8 cm v. 37.3 cm; $p=0.001$) with an engaged fetal head than with an unengaged fetal head. Rupture of membranes appeared to have no significant effect on SFH or birth weight (ruptured v. unruptured: 36.8 cm v. 37.1 cm respectively). The 40 cm SFH cut-off for macrosomia yielded a sensitivity of 83% (10/12), a specificity of 82% (232/282), a positive predictive value of 17% (10/60) and a negative predictive value of 99% (232/234).

Discussion

The simplified formula derived in the first study was successfully validated in the second. The formula offers an easy conversion of SFH to birth weight for midwives or obstetricians looking after women in the active phase of labour at term. The formula is best memorised as a subtraction of

Table I. Influence of BMI, engagement of the fetal head and membrane status on correlation of SFH with birth weight, and on SFH and birth weight

	N	r	Mean SFH ($\pm$ SD) (cm)	Mean birth weight ($\pm$ SD) (g)
BMI (N=488)				
<30 kg/m ²	348	0.62	36.4 $\pm$ 3.2 [†]	3 155 $\pm$ 422 [†]
≥ 30 kg/m ²	140	0.64	38.9 $\pm$ 3.8 [†]	3 298 $\pm$ 453 [†]
Head (N=502)				
Engaged	128	0.56	36.5 $\pm$ 3.5 [†]	3 178 $\pm$ 454
Not engaged	374	0.67	37.2 $\pm$ 3.6 [†]	3 194 $\pm$ 431
Membranes (N=504)				
Intact	241	0.64	37.2 $\pm$ 3.5	3 175 $\pm$ 425
Ruptured	263	0.64	36.9 $\pm$ 3.6	3 203 $\pm$ 445

Statistical significance: Student's t -test for differences in means: [†] $p<0.0001$, [‡] $p=0.0009$, [§] $p=0.05$.
r = correlation coefficient; SD = standard deviation.



5. Examples are an SFH measurement of 33 cm giving an estimated fetal weight of 2.8 kg or one of 41 cm predicting a fetal weight of 3.6 kg. The method provided estimates (68% of estimations in the first study and 65% of estimations in the second study within 10% of the birth weight) that fell in the upper range of accuracies of clinical estimates reported in the literature.³⁻¹⁰ Membrane rupture had no influence on estimations, while an engaged head was associated with an under-estimation of birth weight by about 100 g. Users of the formula could add 100 g to the estimated fetal weight if the head is engaged. The data also suggested that a high BMI could lead to overestimation of fetal weight, possibly because of increased abdominal subcutaneous fat content. However, women with a high BMI tended to give birth to larger infants, thus compensating for such over-estimation.

An SFH cut-off value of 40 cm had good sensitivity and specificity for predicting a birth weight of 4 000 g or more. The greatest strength of this cut-off was its negative predictive value (99%). This means that an SFH of less than 40 cm in a woman in the active phase of labour at term gives a 99% likelihood that the newborn will weigh less than 4 000 g. However, this applies only in populations where macrosomia at birth (birth weight of 4 000 g or more) is relatively rare. Studies of women of black African ethnic origin in southern Africa suggest that the rate of macrosomia at birth is 2.3 - 3.4%,^{24,25} much less than in Europe or North America.^{26,27} Therefore, the predictive findings here related to an SFH of 40 cm should not be applied in communities or environments different from the one studied. The 40 cm cut-off can be recommended for general use in southern Africa for term parturients of black African ethnic origin, to identify women at high and low risk of complications such as shoulder dystocia and cephalopelvic disproportion. This adds to findings from a previous study from Pretoria,¹³ where a 30 cm cut-off was found useful in predicting birth weights of less than 2 000 g in women in preterm labour.

Interpretation of these results must take into account some limitations. While the validation study found the results of the derivation study to be repeatable and therefore probably reliable, it is important that the method of SFH measurement be followed exactly as recommended²³ for the results to be reproduced elsewhere. The derived formula should only be used at term in women in the active phase of labour. Simple inspection of the derived regression line (dotted line in Fig. 1) shows that the formula becomes unreliable at the extremes of birth weights at term. Therefore, with SFH measurements of greater than 40 cm it is enough to consider that the infant will have a birth weight above the average, without aiming to predict the birth weight with any precision. For SFH measurements less than 33 cm there is similar inaccuracy, and a guess that the infant will be of below-average weight is sufficient. The results of this study are not able to give information about SFH in small babies, because the study specifically excluded all gestations of less than 37 weeks. Also,

SFH measurement as described here may not be meaningful if the gestation is unknown. Careful clinical palpation or ultrasound scanning would need to be done first to determine whether the pregnancy is likely to be at term or not.

SFH measurement in labour, with or without the use of formulas or cut-offs, can assist in the prediction of birth weight. However, only randomised controlled trials will be able to demonstrate whether SFH measurements during labour will make a difference in terms of intrapartum interventions such as referral, oxytocin use and caesarean section, or fetal outcomes such as asphyxia, birth trauma and perinatal death.

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