Estimation of gestational age from fundal height: a solution for resource poor settings

Lisa J. White¹,², Sue J Lee¹,², Kasia Stepniewska¹,², Julie A. Simpson²,³, Saw Lu Mu Dwell⁴, Ratree Arunjerdja⁴, Pratap Singhasivanon⁷, Nicholas J. White¹,², Francois Nosten¹,²,⁴, Rose McGready¹,²,⁴

¹Centre for Clinical Vaccinology and Tropical Medicine, Nuffield Department of Clinical Medicine, John Radcliffe Hospital, University of Oxford, Oxford, UK
²Faculty of Tropical Medicine, Mahidol University, Bangkok, Thailand
³Centre for Molecular, Environmental, Genetic and Analytic Epidemiology, School of Population Health, The University of Melbourne, Melbourne, Australia.
⁴Shoklo Malaria Research Unit, PO Box 46 Mae Sot, Tak, Thailand, 63110

Short Title: Estimation of gestational age from SFH
SUMMARY

Many women in resource poor settings lack access to reliable gestational age assessment because they do not know their last menstrual period (LMP), there is no ultrasound and methods of newborn gestational age dating are not practiced by birth attendants. A bespoke multiple-measures model was developed to predict the expected date of delivery (EDD) determined by ultrasound. The results are compared with both a linear and a non-linear model. Prospectively collected early ultrasound and serial symphysis-pubis fundal height (SFH) data were used in the models. The data were collected from Karen and Burmese women attending antenatal care on the Thai-Burmese border. The multiple-measures model performed best resulting in a range of accuracy depending on the number of SFH measures recorded per mother (for example 6 SFH measurements resulted in a prediction accuracy of ± 2 weeks). SFH remains the proxy for gestational age in much of the resource poor world. While more accurate measures should be encouraged we demonstrate that a formula that incorporates at least three SFH measures from an individual mother and the slopes between them provides a significant increase in the accuracy of prediction compared with linear and non-linear formulae also using multiple SFH measures.

Keywords: symphysis fundal height; gestational age; estimation; formula; ultrasound
INTRODUCTION

Ultrasound assessment of gestational age up to 24 weeks provides the most accurate prediction of expected date of delivery and is more reliable than last menstrual period (Verburg et al., 2008, Nakling et al., 2005). Although accurate gestational age assessment is not a problem unique to resource poor settings (Thorsell et al., 2008, Rosenberg et al., 2009, Hoffman et al., 2008), there is lower availability of ultrasound dating for women in these settings (Rijken et al., 2009, Traisathit et al., 2006, Bussmann et al., 2001). Due to the sheer numbers of births and economics in developing countries the last menstrual period remains the most widespread predictor of gestational age (Spencer and Aldler, 2008, Andersen et al., 1981). In some cultures, particularly where literacy levels are low, last menstrual period can be very unreliable (Rijken et al., 2009). In such settings methods to date such pregnancies have relied on inexpensive tools including validated scored assessments of superficial and neurological newborn criteria, for example, the Dubowitz (Mitchell, 1979, Dubowitz et al., 1970, Rosenberg et al., 2009, Vik et al., 1997) and Ballard or modified Ballard (Rosenberg et al., 2009, Verhoeff et al., 1997, Moraes and Reichenheim, 2000, Ballard et al., 1991, Ahn, 2008, Sunjoh et al., 2004) score. Training and ongoing quality control of testers is needed to maintain the accuracy of these methods. The symphysis-pubis fundal height (SFH) measurement is also widely available, routinely practiced in nearly all antenatal settings in the world and simple to perform. While Neilson’s Cochrane review concludes that there is not enough evidence to evaluate the use of SFH during antenatal care, it may be the only data collected and reported in an antenatal card, in much of the resource poor world, that provides a clue to the gestation of pregnancy (Neilson, 2000). In the past 20 years SFH has taken a back seat to ultrasound in terms of gestating pregnancies but resource rich (Gardosi and Francis, 1999, Liang et al., 2008, Indraccolo et al., 2008, Indira et al., 1990, Stuart et al., 1989, Rosenberg et al., 1982) and poor (Verhoeff et al., 1997, Traisathit et al., 2006, Challis et al., 2002, Andersson and Bergstrom, 1995, Krishna et al., 1991) countries use SFH in routine practice as a low technology method for monitoring of fetal growth and identifying intra-uterine growth restriction.

Attempts have been made to use SFH and other factors such as maternal weight and ultrasound prediction to infer excess fetal weight with moderate success (Wikstrom et al., 1993, Onah et al., 2002, Mazouni et al., 2006). A single SFH at delivery was not reliable enough to estimate fetal weight in South Africa (Wikstrom et al., 1993, Onah et al., 2002, Mazouni et al., 2006, Bothner et al., 2000) but was felt to be useful in rural Tanzania (Walraven et al., 1995). SFH after 24 weeks has been used to schedule the start of zidovudine therapy to prevent mother-to-child transmission of HIV when LMP or US were not available or reliable (Traisathit et al., 2006). In one UK based study an obstetrician blinded to the LMP overestimated gestation by 6 weeks when assuming SFH at the umbilicus was equivalent to 20 weeks (Jimenez et al., 1983). SFH has been used as a proxy for
gestational age in Africa (Andersson and Bergstrom, 1995) and racial differences in SFH growth rates have also been documented (Buhmann et al., 1998, Grover et al., 1991). Crosby et al. and Engstrom et al. emphasize the considerable inter and intra observer error in their study of SFH measurements (Engstrom et al., 1989, Engstrom et al., 1993, Crosby and Engstrom, 1989). The shape of the SFH curve with gestation has been plotted by various groups who established population curves again in the interests of being able to detect growth restriction (Thompson et al., 1997, Steingrimsdottir et al., 1995, Rai et al., 1995, Medhat et al., 1991, Linasmita and Sugkraroek, 1984, Engstrom and Work, 1992, Engstrom et al., 1993, Buhmann et al., 1998, Azziz et al., 1988). Two of these groups describe the use of polynomial regression as the best method to fit the SFH data (Steingrimsdottir et al., 1995, Engstrom and Work, 1992). Few studies have modeled SFH to predict gestational age at birth (Andersson and Bergstrom, 1995).

In refugee camps and migrant antenatal clinics on the Thai Burmese border the majority of women are unable to provide a reliable date of the last menstrual period (Rijken et al., 2009). In previous publications on malaria in pregnancy from the same area, a formula for predicting gestational age using SFH in these women was used (McGready et al., 2001, Nosten et al., 1999) and was found to predict gestational age with an accuracy of ±6.26 weeks.

Variations in fetal size at a given gestation can be converted into differences in gestational age. This applies just as well to ultrasound estimates (current gold standard) though this is rarely discussed (Henriksen et al., 1995). Henriksen and colleagues, (Henriksen et al., 1995) explored this in detail in relation to good quality history of LMP and an early ultrasound measurement of early biparietal diameter (BPD) in 3,606 women. They report that factors that reduce fetal size e.g. female sex of babies and maternal smoking, can distort the relative risk of preterm or post term delivery by 10-20% when gestational age is based on late ultrasound not LMP. Despite highly accurate fetal measurements at present, an inherent error remains in any prediction of gestational age. This manuscript refines the estimation of gestational age from SFH in women using early ultrasound derived gestation as a gold standard. Three models (formulae) were developed and compared for accuracy of predictive power. The aim of modelling SFH in this particular population was to ascertain the most reliable method of gestating pregnancies when no other reliable measure of gestation was available.

**METHODS**

The data

Shoklo Malaria Research Unit (SMRU) is located on the Thai-Burmese border and has studied the epidemiology, prevention and treatment of malaria in pregnancy since 1986. It has five established clinics, one of which is
based in refugee camp Maela, where the Karen minority group from Burma are the principal inhabitants. In all its clinics SMRU runs a program of antenatal care (ANC) to detect and treat all parasitaemic episodes during pregnancy through weekly malaria screening in order to prevent maternal death (Nosten et al., 1991). Since the inception of this ANC program, all pregnant women have been encouraged to attend as early as possible in pregnancy. At the first visit (usually between 8-14 weeks gestation), ultrasound is used to determine viability, detect multiple pregnancy and estimate gestational age. A second scan is performed at 18-24 weeks to confirm gestation, viability and placental position. As this is the only antenatal and delivery service easily accessible to women in these areas all records are filed in a similar manner to a hospital archive. Patient files are computerized and can be retrieved as needed. Post-term pregnancies are managed by induction. At the time of data collection the upper limit to commence induction was 42 weeks. Patients were also included in the management plan and some women refused induction.

Anonymous data from pregnancies with live born, congenitally normal, singleton outcomes were collated. The serial SFH measurements (cm) and their respective date of measurement in mothers with pregnancies dated by ultrasonography between 8+0 - <11+0 weeks (crown rump length measured) and 16+0 - <21+0 weeks (biparietal diameter, femur length and abdominal circumference measured) were included in a database. The period of data collection was from April 2002 to May 2006. Women with less than three serial SFH measurements or SFH measurements that were less than 2 weeks apart were also excluded.

SFH was examined on every woman on a weekly basis until it was first measured. SFH was then done at least monthly and often weekly from 34 weeks onwards. After making sure the bladder was empty, the woman lay down on her back while the midwife, sitting to the patient’s right, located the symphysis pubis. The metal tip (at zero cm) of a standard soft tape measure (manufactured by Butterfly® in the People’s Republic of China) was placed at the upper border of the symphysis pubis. SFH was the distance measured from the top of the symphysis pubis to the depression in front of the pad of the middle finger marking the top of the uterine fundus, in the midline of the woman’s abdomen. Measures were rounded to the nearest centimeter. Midwives recorded SFH into the antenatal record to the nearest round number i.e. if >=0.5 the fundal height measurement was rounded up and if < 0.5 rounded down, and only at that point was it compared to ultrasound gestation for patient care.

Variables that described the date of the first antenatal consultation, the date of birth, maternal age, gravidity and parity, weight, height and body mass index (measured at the first consultation date), smoking during pregnancy and documented P.falciparum and P.vivax malaria during pregnancy were also collated.
Models

Three models were considered for the prediction of gestational age using SFH measurement. The first was a linear formula using a single SFH measure, the second was a non-linear formula using a single SFH measure and the third was a formula that used multiple measures of SFH combined with the dates of each measurement.

Model 1 requires only a single measure of SFH and uses linear regression to model the gestational age. This is the standard linear formula (Nosten et al., 1999) based on a linear relationship between Dubowitz gestational age assessment (Dubowitz et al., 1970) and SFH measurements (n=100 women with normal pregnancies).

\[ G = (a_1 H + a_2) \]

where \( G \) is the expected gestational age in weeks determined by ultrasound at the date of the SFH measurement and \( H \) is the SFH in cm with two estimated parameters \( a_1 \). This model was transformed to a multiple measure model by, for each mother, taking the mean of the gestational age at birth predictions from each of her SFH measures.

Model 2 is a non-linear formula for predicting gestational age. A non-linear formula was considered because when SFH is plotted against gestational age at time of measurement for each mother growth appears to be initially linear followed by a plateau. A functional form was chosen that would allow such a shape while limiting the number of parameters to be estimated to only 3.

\[ G = -\ln \left( \frac{\ln \left( \frac{b_1}{H} \right)}{b_2} \right) + b_3 \]

where \( G \) is the gestational age in weeks and \( H \) is the SFH in cm with three estimated parameters \( b_1 \). This model was transformed to a multiple measure model by, for each mother, taking the mean of the gestational age at birth predictions from each of her SFH measures.

Model 3 is a multiple measure algorithm as follows:
(1) Start with a list of SFH with the date they were measured for each mother

(2) Generate all the “sets of three” of these measures. E.g. five measures would result in 6 “sets of three” measures: (1,2,3], [1,2,4], [1,2,5], [2,3,4], [2,3,5], [3,4,5].

(3) For each “set of three” measures from each mother, predict the gestational age predicted at the final measure for that mother in two ways:

   (a) Mean of three linear models. \( G = t_f + c_{L0} + \frac{1}{3} \sum_{i=1}^{3} (c_{L1}H_i - t_i) \)

   (b) Combination of 3 fundal heights and 3 gradients.

   \[ G = t_f - t_3 + c_0 + \sum_{i=1}^{3} c_i H_i + \sum_{(i,j)\in\{(1,2),(1,3),(2,3)\}} k_{ij} \frac{H_j - H_i}{t_j - t_i} \]

(4) If the gestational age predicted by 3(b) is between \( G_{\text{min}} \) and \( G_{\text{max}} \) then use this for time \( t_f \), otherwise use the prediction using 3(a).

(5) For each mother, take the mean of the gestational age predictions for each set of three measures

This system has 11 estimated parameters: \( c_{L0}, c_{L1}, c_0, c_1, c_2, c_3, k_{12}, k_{13}, k_{23}, G_{\text{min}} \) and \( G_{\text{max}} \).
**Fitting method and model comparison**

Chi-squared was used as a measure of goodness of fit and the chi-squared value was minimised within Excel using the simplex method. This approach represents a weighted least squares minimisation where the mean is a proxy for the variability. A subset of the data was produced by randomly selecting the data of 50% of the mothers included in the study population. The model was fit to this subset and then used to predict the gestational age for the remaining data. Results for the predictions of gestational age by ultrasounds and Models 1 to 3 in the form of:

A: Relative percentages of predicted premature (<37 weeks gestation), term (37 to < 42 weeks gestation) and post-term (≥42 weeks gestation) births.

B: The model’s potential to predict premature births in the form of a table of: true positive; true negative; false positive; false negative; sensitivity; specificity

C: The model’s potential to predict post term births in the form of a table of: true positive; true negative; false positive; false negative; sensitivity; specificity

D: histogram of predicted gestational age at birth

E: histogram of residual error (i.e. how does the model prediction using only SFH compare with the ultrasound prediction - for a good model, the distribution should be symmetrical about zero and have a small spread)

F: Mean residual error

G: Percentage born within 2 weeks of predicted date of birth.

For the following:

1. Ultrasound data (gold standard thus no result for D)
2. Model 1 (linear model)
   a. On 1st SFH
   b. On mid SFH
   c. Average prediction from all SFH
3. Model 2 (non-linear model)
   a. On 1st SFH
b. On mid SFH

c. Average prediction from all SFH

(4) Model 3 (multiple measures model)

**Risk factors**

For Model 3, the predicted gestational age was adjusted for mother level factors (each of: mother weight; mother height; mother BMI; mother age; the gravida of the current pregnancy; the parity of the current pregnancy; whether the mother smoked or not; slide positive for *Plasmodium falciparum*; slide positive for *Plasmodium vivax*). Inclusion of these factors was checked for statistical significance using the chi-squared distribution.

**RESULTS**

**Preliminary data analysis**

Overall 2,437 women with ultrasound dated pregnancies had a total of 7,476 SFH measurements with their corresponding dates. The demographic variables of the women included in the model were summarized (Table 1). For each mother, the series of SFH measurements was plotted against the gestational age, inferred from the best (CRL preferred over BPD) single ultrasound estimate at the time of measurement (Figure 1). There was a large variation in gestational age for a single SFH (about 10 weeks, Figure 1). The variation in SFH for a given gestational age was a combination of the variation between measurements and the variation between individuals. Each mother has a different growth pattern for SFH versus gestational age (Figure 2). For example, a plot of the profiles for four mothers (Figure 2: black, red, blue and green) shows that the profiles for each mother can be quite different in shape. The red and black appear almost parallel with the red always higher than the black. The green starts lower than the black, but reaches the red line level by the final measure, whereas the blue starts at about the same level as the red but is closer to the black level by the final measure. Hence the challenge in estimating gestational age from multiple measures of SFH in a single woman was to developing a method to accurately account for the placement of an individual growth curve on the gestational age axis.

*Table 1 near here*

*Figure 1 near here*
Parameter estimates

For each model, the following parameter values were estimated using the method described earlier:

**Model 1:** \(a_1=4.5\) and \(a_2=1.0\).

**Model 2:** \(b_1=53.96\), \(b_2=0.055\), \(b_3=24.82\).

**Model 3:** \(c_{10}=4.1\), \(c_{11}=0.95\), \(c_0=12\), \(c_1=1.1\), \(c_2=-0.7\), \(k_{12}=0.09\), \(k_{13}=7\), \(k_{23}=-0.1\), \(G_{\text{min}}=33\) and \(G_{\text{max}}=42\).

The Electronic Supplementary Material includes full details of all the model fits. Model 3 was the best fitting model most closely mimicking the distribution of gestational age at birth as predicted by ultrasound and with the lowest variance in residual error.

The 95% prediction interval was calculated for the predictions of gestational age by Model 3 for mothers with 3 to \(\geq 10\) measurements (Table 2) demonstrating that the accuracy of the prediction was not improved by using more than 6 measurements. Six to seven SFH measurements produced 95% prediction intervals of (-16 to 14) and (-15 to 16) days (Table 2).

**Table 2 near here**

The predicted gestational age was adjusted for mother level factors (each of: mother weight; mother height; mother BMI; mother age; the gravida at the current pregnancy; the parity of the current pregnancy; whether the mother was primigravida or not; whether the mother smoked or not; slide positive for *Plasmodium falciparum*; slide positive for *Plasmodium vivax*) and inclusion of these factors was checked for significance using the chi-squared distribution. The inclusion of mother level factors does not significantly improve the fit of Model 3 most likely because most pregnancies are in normal healthy non smoking multigravid women.

Model 3 was used to explore the cut off for gestational age for optimal prediction of premature births (Table 3). For predicting a premature birth correctly, increasing the cut off increases sensitivity at the expense of specificity. A cut off of 37.6 will give a high sensitivity with more true positives and true negatives and a much lower ratio of true to false positives. This indicates that while the use of Model 3 with an adjusted cut off for defining a premature birth is the most effective model for defining premature birth. The ranges defining
premature (<37 weeks gestation), term (37 to < 42 weeks gestation) and post-term (≥42 weeks gestation) births in this dataset were approximately 5, 5 and 2 weeks. These ranges are small and very similar to the best error.

**Table 3 near here**

We have produced a file within Excel that uses Model 3 to estimate gestational age (Figure 3). It requires a minimum of three input values of SFH with the dates of measurement. This can be downloaded freely (from [http://www.tropmedres.ac/research/mathematical-modelling.html](http://www.tropmedres.ac/research/mathematical-modelling.html)) for use on personal computers.

**Figure 3 near here**

**DISCUSSION**

There have been many publications of SFH based fetal growth curves in the literature (Challis et al., 2002, Faustin et al., 1991, Westin, 1977) including two from Thailand (Linasmita and Sugkraroek, 1984, Praditstawong, 1987). We have derived a similar growth curve for the data presented here (Figure 1, right). The inherent variability of the SFH measurement observed in this data set was a gestational age range of about 10 weeks for a single measurement. The distribution of gestation compared for the 7,476 SFH measurements in the 2,437 women presented here (Figure 1, left) was, as expected, larger than that observed by Linasmata in 1,295 SFH measurements in 451 women from Bangkok (Linasmita and Sugkraroek, 1984) and in the 1,498 SFH in 321 women from Prachuap, one of the central provinces in Thailand (Praditstawong, 1987). Growth curves of SFH against gestational age can vary by country as reported by Challis from a comparison of 11 studies of SFH measurements and ethnic group (Challis et al., 2002). This would imply that Model 3 with the parameter estimates for the population presented here may not be applicable to other countries, but the model itself could be re-parameterised for another country by using the data that is normally used to produce SFH growth curves and repeating the estimation process described here (that is training the model to a new data set from a different population). In addition it is likely to give more accurate predictions than other methods that use SFH. Thus while this model is produced for refugee and migrant, predominantly Karen women of Asian origin, it has the potential to be adapted to other groups.

The multiple measures model (Model 3) predicts gestational age from SFH with consistently higher accuracy than other methods. The multiple measures model was compared with linear and non-linear models using the same data set and was found to provide more accurate results using seven criteria (Additional file). The accuracy
of Model 3 applied to the data set presented here was also compared with previously published methods applied to other data sets. The method by Andersson and Bergtrom (Andersson and Bergstrom, 1995) resulted in 45% (270/604) cases delivered within 2 weeks of the predicted date, whereas Model 3 gives 62% delivery within 2 weeks of the predicted date. The method used by Faustin et al. (Faustin et al., 1991) resulted in an average deviation from the real gestational age of 2 to 3 weeks whereas for Model 3 this deviation was less than one week. Reading gestational age from growth curves with 5th and 95th percentiles or 10th and 90th percentiles tends to result in accuracies of within 5 to 8 weeks (i.e. ± 2.5 to 4 weeks) (Challis et al., 2002, Linasmita and Sugkraroek, 1984, Westin, 1977) whereas the multiple measures model predicts with an accuracy of within 4 weeks (95% prediction interval) when 6 or more SFH measurements are used. The reason why the multiple measures model tends to predict gestational age with a higher accuracy than other SFH methods is because it incorporates not only the height measurements but also the slopes (gradients) between them. This allows the shape of the curve to be accounted for in terms of the relationship between the SFH and the growth velocity, a measure that has been shown in other recent studies using ultrasound to be highly informative (Bottomley et al., 2009).

The multiple measures model should not be used to predict a binary variable such as prematurity (that is, to predict whether the birth will be either premature or not premature). The reason for this is that the range of gestational ages of premature births is about 5 weeks and this is very close in size to the prediction interval which at best is about 4 weeks. Thus it is expected that many births on the border between term and preterm would be misclassified using the multiple measures model. However, the model prediction is reliable as a continuous variable. This method is also robust to other risk factors including mother weight, mother height, mother BMI, mother age, the gravida of the current pregnancy, the parity of the current pregnancy, whether the mother smoked or not, slide positive for Plasmodium falciparum and slide positive for Plasmodium vivax.

In summary, given a realistic number (6-7) of repeated SFH measurements, at least 2 weeks apart, with corresponding dates derived from routine ANC, the multiple measures model has the potential to predict gestational age to a higher level of accuracy than previously published methods. It can be applied to the presented population by using the freely available excel spreadsheet. Entry of a series of SFH measurements and the corresponding dates in this spreadsheet will generate a prediction of the date of birth with corresponding accuracy. The model could also be applied to other populations after training to the same data that were used to obtain SFH growth curves and development of a new spreadsheet for predictive purposes could be derived.
The ideal of ultrasound dating for pregnant women worldwide will continue to be constrained by available resources. The cost of SFH measurements and a computer to calculate expected date of delivery is orders of magnitude lower than the cost of an ultrasound machine. Ultrasound performs better if the dating is in the optimum window while SFH allows more flexibility. The study of infectious diseases in pregnancy in resource limited settings needs appropriate technology. Multiple SFH measurements with an appropriate model for inferring gestational age is one such tool (Hofmeyr, 2009).

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DISCLOSURE OF INTERESTS

The authors do not have competing interests.

CONTRIBUTION OF AUTHORSHIP

LJW, SJL, KS and JAS developed the model structures and performed the mathematical analysis. SLMD, RA and RM participated in collecting the data. RM, FN, PS and NJW participated in developing the initial concept of the study and manuscript revision. All authors read and approved the final manuscript.

DETAILS OF ETHICS APPROVAL

This study was approved by Oxford Tropical Research Ethics Committee, OXTREC 28-09.

REFERENCES


### TABLES

**Table 1**

The demographic variables of the refugee and migrant women

<table>
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<th>n</th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Age, yrs</strong></td>
<td>2437</td>
<td>26.5±6.6 [15-48]</td>
</tr>
<tr>
<td><strong>Weight, kg</strong></td>
<td>2435</td>
<td>48 ± 7 [30-90]</td>
</tr>
<tr>
<td><strong>Height, m</strong></td>
<td>1888</td>
<td>1.51 ± 0.53 [1.30-1.68]</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>1887</td>
<td>20.9± 2.8 [12.7-36.5]</td>
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<td>2437</td>
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<tr>
<td><strong>Parity, median</strong></td>
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<td>2 [0-13]</td>
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<td><strong>Primigravida, % (n)</strong></td>
<td>2437</td>
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<td><strong>Smokers, % (n)</strong></td>
<td>2421</td>
<td>30.2 (735)</td>
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<td><strong>P.falciparum, % (n)</strong></td>
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<td>3.9 (95)</td>
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<tr>
<td><strong>P.vivax, % (n)</strong></td>
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<td>9.3 (226)</td>
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<td><strong>SFH measurements</strong></td>
<td>2437</td>
<td>7 [2-16]</td>
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<tr>
<td><strong>EGA by CRL%</strong></td>
<td>2437</td>
<td>67.8 (1652)</td>
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<td><strong>EGA by BPD%</strong></td>
<td>2437</td>
<td>32.2 (785)</td>
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</table>

Numbers expressed as mean±standard deviation [min-max] or % proportion (n)

CRL=crown rump length; BPD=biparietal diameter
Table 2

The 95% prediction interval in days for Model 3 predictions according to the number of SFH measurements

<table>
<thead>
<tr>
<th>Number of fundal height measurements</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<td>-15</td>
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<td>upper limit</td>
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<td>14</td>
<td>16</td>
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Table 3

Exploration of the relationship between the cutoff gestational age for defining premature birth and the predictive power of the model for this category.

<table>
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<tr>
<th>cutoff</th>
<th>% positive predictive power</th>
<th>% negative predictive power</th>
<th>% sensitivity</th>
<th>% specificity</th>
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<tr>
<td>37</td>
<td>52</td>
<td>97</td>
<td>46</td>
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<td>37.2</td>
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</tr>
<tr>
<td>39</td>
<td>13</td>
<td>98</td>
<td>81</td>
<td>66</td>
</tr>
</tbody>
</table>
FIGURE LEGENDS

Figure 1: Left: plot of symphysis fundal height (SFH) against gestational age estimated using ultrasound for all mothers in the study. Right: plot of the mean SFH (solid black) for each gestational age with 10th and 90th percentiles (dashed black). Both graphs show the variation associated with a SFH of 20cm (dashed red).

Figure 2: Plot of four example mothers to demonstrate the variation in symphysis fundal height (SFH) growth rates at the mother level.

Figure 3: A screenshot of the Shocklo Symphysis Fundal Height Calculator.