PLOS ONE

RESEARCH ARTICLE

Measurement of symphysis fundal height for gestational age estimation in low-to-middle-income countries: A systematic review and meta-analysis

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Abstract

In low- and middle-income countries (LMIC), measurement of symphysis fundal height (SFH) is often the only available method of estimating gestational age (GA) in pregnancy. This systematic review aims to summarize methods of SFH measurement and assess the accuracy of SFH for the purpose of GA estimation. We searched PubMed, EMBASE, Cochrane, Web of Science, POPLINE, and WHO Global Health Libraries from January 1980 through November 2021. For SFH accuracy, we pooled the variance of the mean difference between GA confirmed by ultrasound versus SFH. Of 1,003 studies identified, 37 studies were included. Nineteen different SFH measurement techniques and 13 SFH-to-GA conversion methods were identified. In pooled analysis of five studies (n = 5838 pregnancies), 71% (95% CI: 66–77%) of pregnancies dated by SFH were within ±14 days of ultrasound confirmed dating. Using the 1 cm SFH = 1wk assumption, SFH underestimated GA compared with ultrasound-confirmed GA (mean bias: -14.0 days) with poor accuracy (95% limits of agreement [LOA]: ±42.8 days; n = 3 studies, 2447 pregnancies). Statistical modeling of three serial SFH measurements performed better, but accuracy was still poor (95% LOA ±33 days; n = 4 studies, 4391 pregnancies). In conclusion, there is wide variation in SFH measurement and SFH-to-GA conversion techniques. SFH is inaccurate for estimating GA and should not be used for GA dating. Increasing access to quality ultrasonography early in pregnancy should be prioritized to improve gestational age assessment in LMIC.

Introduction

Globally, measurement of symphysis-fundal height (SFH)–the distance from the symphysis pubis to the top of the uterine fundus–is routinely used in clinical practice for monitoring of fetal growth during pregnancy to identify fetuses at higher risk for perinatal morbidity and mortality. International reference standards for SFH at each week of gestation have been developed for healthy fetal growth based on optimally healthy cohorts of pregnant women [1, 2].

While SFH is primarily used for fetal growth monitoring in high-income countries (HIC), SFH is also commonly used in low- and middle-income countries (LMIC) to estimate gestational age (GA), due to lack of access to more accurate dating methods [3]. Accurate pregnancy dating is necessary for clinical decision-making, including targeted administration of life-saving interventions like antenatal corticosteroids to mitigate preterm complications and the identification and triage of preterm infants [4]. Ultrasound in early pregnancy before 20 weeks' gestation has the highest accuracy for gestational age dating, and new sonography parameters and equations for dating in late pregnancy have shown improved accuracy [5–7]. However, access to ultrasound remains sparse in LMIC. Maternal recall of the first day of the last menstrual period (LMP) is another commonly used method to date pregnancies, but its accuracy is limited by variation in menstrual cycle length, misinterpretation of early bleeding, and poor recall.

When ultrasound and reliable LMP are not available, SFH is frequently used for GA estimation because it is a simple, low-cost, and feasible technique that can be performed by lay health workers [3]. However, fundamental flaws in using SFH for this purpose include the underlying assumption that fetal size approximates GA, and that every fetus of a certain size is the same GA. Fetal size is influenced by genetic factors and normal biologic variation, and fetal growth is influenced by maternal nutrition, health, and morbidities, including infections, pregnancy complications, or environmental exposures. Risk factors for poor fetal growth are much more prevalent in LMICs [8–10]. The use of standard SFH curves from high income settings with low prevalence of these risk factors would, thus, tend to systematically underestimate GA when applied to a population with high prevalence of fetal growth restriction. Further confounding the use of SFH is the lack of standardized methods for measurement of SFH and converting the measurement to gestational age.

The 2016 World Health Organization (WHO) ANC Guidelines concluded that there was inadequate evidence on the role of SFH monitoring in antenatal care [11]. Previous systematic reviews have assessed SFH measurement as a tool for fetal growth monitoring [12–15], however, there is limited data on the accuracy of SFH for estimation of GA. One recent systematic review assessed maternal SFH for GA estimation and concluded "ultrasound-based" measures were more accurate [7], though few SFH studies were identified and prediction accuracy was not summarized for SFH. The purpose of this systematic review is to summarize methods of SFH measurement for GA estimation, existing population-based SFH references, and the accuracy of SFH measurement specifically for GA estimation, among general obstetric populations in LMIC, populations representative of those who would be seen in routine clinical practice in these settings.

Methods

Search strategy

A systematic review of the published and gray literature from PubMed, Embase, Cochrane, Web of Science, POPLINE, and the WHO Global Health Libraries and regional databases was conducted from January 1980 up to November 2021. The review was registered with the

International Prospective Register of Systematic Reviews (CRD42015020499) and reported according to the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) statement [16] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [17]. The detailed search terms are available in S1 Text in S1 Appendix. Articles were also identified from bibliographies of manuscripts of interest. No language restrictions were applied. Abstracts of non-English articles were translated via Google Translate, and if eligible, the full text was translated into English by fluent speakers. For meeting abstracts, attempts were made to contact the corresponding author to obtain the updated, full text of research.

Studies were eligible for inclusion if the study provided any information about a technique for measuring SFH or reported inter- or intra-rater reliability between SFH measurers. We included studies that reported at least one statistic comparing gestational age determined by SFH and another method (ultrasound or last menstrual period) and enrolled a general, unselected obstetric population. Finally, we also included studies that reported population-based SFH measurements (average or median) by week of pregnancy for cohorts in LMICs with ultrasound confirmed dating. This subset of studies was limited to LMIC-based studies as SFH charts are more likely to be used for GA-dating in LMIC settings, while in HIC, pregnancies are typically dated by ultrasound and SFH charts are used for fetal growth monitoring purposes. Countries were classified as LMIC according to the World Bank at the time of the study's publication [18].

Studies were excluded if they enrolled a highly selected or specialized subpopulation that did not represent the general obstetric population (e.g., only HIV-positive mothers, or strict eligibility criteria of optimally healthy populations within narrow BMI thresholds; with the exception of studies that reported on inter- or intra-reliability between SFH measurers), editorials or reviews without original data, individual case reports, and duplicate search results. We also excluded studies that had <50 patients, or reported only SFH accuracy data for growth monitoring (e.g., determining estimated fetal weight or small-for-gestational age). Institutional Review Board approval was not required for this work.

Data extraction

Two independent researchers reviewed studies and extracted relevant data into a standard Excel file created for the purpose of this review (S2 Text in S1 Appendix). Differences were resolved through discussion between the two reviewers, or by a third independent reviewer. Characteristics of the included studies can be found in S1 Table in S1 Appendix.

Study quality assessment

For studies that assessed the accuracy of SFH to estimate GA, the risk of bias was graded by two independent reviewers using the Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool [19], which was modified for the nature of this review (S3 Text in S1 Appendix). Each study was evaluated for potential biases across four domains: (i) patient selection, (ii) test method, (iii) reference (i.e., gold) standard, and (iv) patient flow and timing in pregnancy of SFH measurements. Factors that were considered to potentially influence the relationship between SFH and GA were selected for grading of study quality, and also considered for sub-group/sensitivity analysis. Studies with a gold standard GA based on ultrasound or by ultrasound-confirmation of the menstrual dates (hereafter referred to as 'ultrasound-confirmed' GA) were graded as highest quality given that the ultrasound confirmation of dating would be considered as closest to the "actual" truth.

Statistical analysis

Stata 15 (StataCorp, College Station, TX) was used for analyses. Studies were grouped by WHO world region and GA gold standard; data were summarized by these groupings using simple descriptive statistics. Data presented in the main manuscript are studies with the highest quality ultrasound-confirmed GA; data from studies identified with the lower quality LMP based dating are shown in the webappendix. For population-based SFH reference studies from LMICs, studies were grouped by the WHO world region given *a priori* differences in fetal size and rates of growth restriction between Africa and Asia [20].

To assess data on the accuracy of GA estimated by SFH, we summarized data on the difference in GA determined by SFH compared to ultrasound-confirmed GA (reference gold standard), as well as the distribution or spread of the differences (standard deviation [SD] of the mean difference, 95% limits of agreement in Bland-Altman analysis, or 95% prediction error in statistical models). For studies that reported Bland-Altman limits of agreement (LOA), the standard deviation was calculated by dividing the 95% LOA/(2*1.96). For studies that reported upon prediction intervals from statistical models, we assumed normality and symmetry of the distribution of residuals. The pooled variance and standard deviation were calculated using the following formula:

$$Variance_{pooled} = \frac{\sum_{i=1}^{k}(n_i - 1)s_i^2}{\sum_{i=1}^{k}(n_i - 1)}$$

To pool studies in which investigators reported upon the proportion of test measured within ±1 to 2 weeks of the gold standard, proportions were logit transformed and standard errors calculated with the equation: SE(logit(p)) = SE(p)/(p*(1-p)), where p is the proportion [21]. Meta-analysis was conducted with a random effects model. Heterogeneity was assessed with the Higgins I^2 statistic.

Assessment of publication bias is recommended by Cochrane for meta-analyses with ≥10 studies, as fewer studies do not have adequate power to distinguish real asymmetry from chance [22]. We had no analyses meeting this threshold and were unable to assess for publication bias.

Results

Of 1606 papers identified, 1003 unique studies were screened by title/abstract, and 37 articles were included (Fig 1). Detailed characteristics of included studies can be found in S1 Table in S1 Appendix. The studies were published between January 1983 and May 2020, with 30 studies from LMICs (12 from Africa, 16 from Asia, 1 from South America, 1 multiregional) and 7 from HIC (3 from North America, 1 from Europe, 1 from Asia, 1 from Oceania, 1 multiregional). Nineteen studies had a gold standard of ultrasound-confirmed GA, 18 studies had LMP-based dating. For additional details on individual study methods, see S1 Table in S1 Appendix.

For studies of diagnostic accuracy, study quality was summarized using QUADAS-2 in S1 Fig in S1 Appendix. Half of the studies (n = 9/17, 53%) had a high risk of bias related to the SFH methodology due to limited descriptions of SFH measurement technique or method of calculation of GA from SFH, absence of quality control procedures, and/or lack of blinding to gold standard GA dating. About 40% (n = 7/17) of the included studies had a high risk of bias related to the gold standard methodology because the gold standard was LMP or not well described.

SFH measurement techniques

We identified 19 different methods of measuring SFH reported in the literature (Table 1), [23–42] most of which were described in a 1993 review article by Engstrom and Sittler [43].
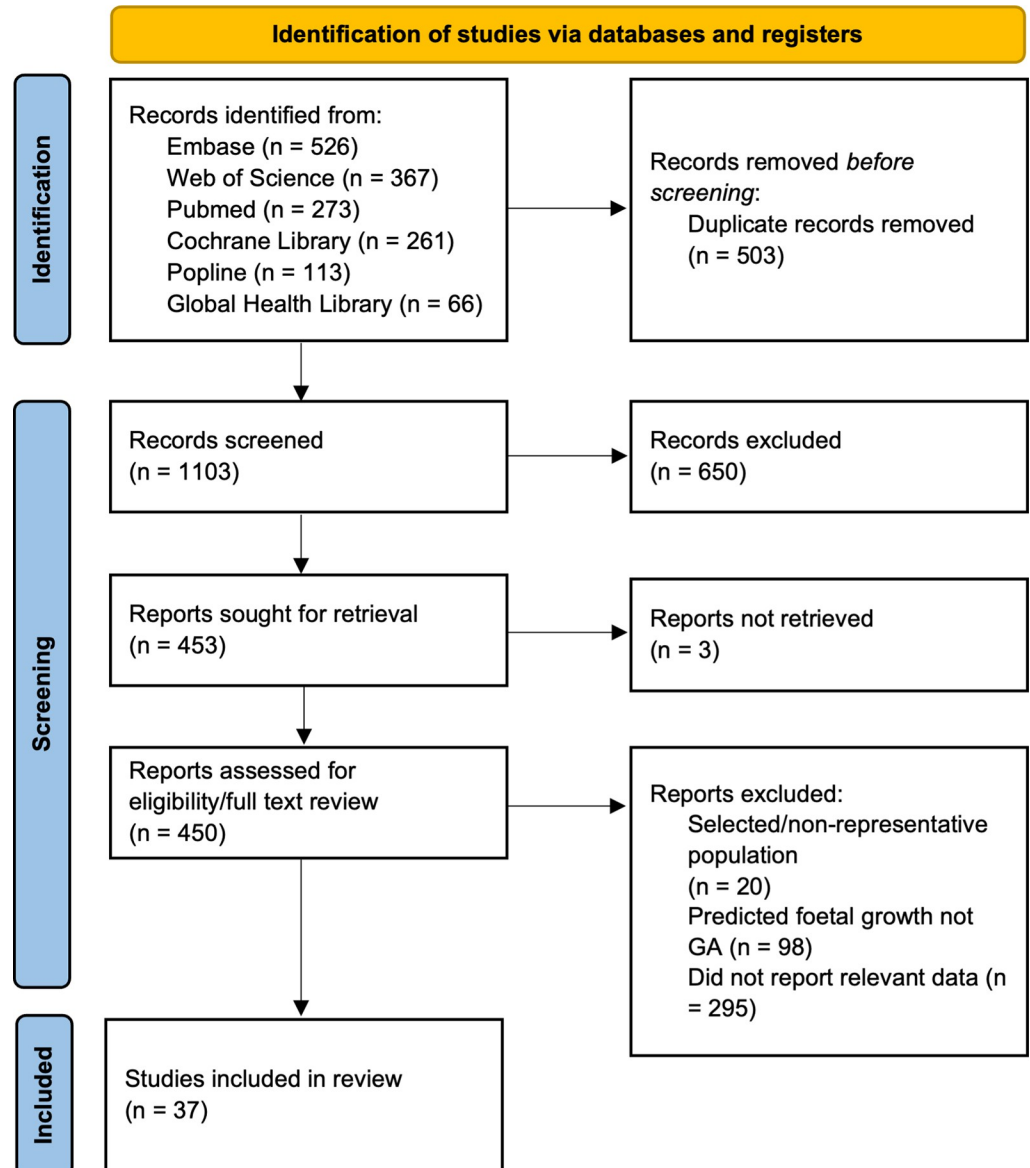
Fig 1. PRISMA flow diagram for systematic literature review of symphysis fundal height for gestational age estimation.

Techniques differed by the instrument used to measure SFH (tape measure, caliper, finger-width, ultrasound); choice of superior and inferior landmarks; axis of measurement (vertically at the midline or diagonally at the highest point of the uterine fundus or fetal pole); and by whether the tape was held in contact with the skin of the maternal abdomen or taken straight between two hands.

SFH to GA conversion methods

Across the studies identified in the review, we identified a wide range of methods by which SFH is used to estimate GA (S2 Table in S1 Appendix). A commonly used clinical rule of thumb is that 1 cm is equal to 1 week for ≥20 weeks' gestation (referred to as 1cm = 1wk in this report) [44, 45]. A similar rule known as McDonald's Rule, first published in 1906,

Table 1. Symphysis fundal height measurement techniques.

Author(s) of Technique *Country*	Description	Instrument	Upper to Lower Anatomic Landmarks
Tape Measure Technique			
Spiegelberg (1865, 1887) *Germany*	Midline measurement identifying the margin of the fundus by percussion and measuring the "Length of the Line" connecting the highest point of the fundus with upper edge of symphysis pubis	Tape measure	Highest point of fundus to upper edge of the symphysis pubis
McDonald measurement (1906, 1910) *USA*	One hand holding the tape in upper border of symphysis pubis and extended fingers of other hand placed perpendicular of uterine fundus then the tape measure grasped with fundal hand and tape is pressed in palm of the hand	Tape measure	Uppermost point of the uterine fundus to upper border of the symphysis pubis
Spalding (1913) *USA*	Midline measurement with one end of tape in the upper border of symphysis pubis, other in xiphoid process then locating the uppermost point of fundus and read the corresponding number.	Tape measure	Uppermost point of the uterine fundus to upper border of the symphysis pubis
Willson (1958) *USA*	Extended finger of each hand held perpendicular to uterine fundus and symphysis pubis, and tape measure is held in straight line between two hands. Tape measure not in contact with maternal abdomen at any point.	Tape measure	Uppermost point of the uterine fundus to symphysis pubis
Westin (1977) *Sweden*	Measured along the longitudinal the axis of uterus, regardless if in the midline. Tape is in contact with maternal abdomen, but not necessarily brought completely to the curve of fundus. Tape is held in end of long axis of uterus	Tape measure	Uppermost point of the uterine fundus to inferior border of symphysis pubis
Belizan (1978) *Argentina*	Measured from the upper border of the symphysis pubis to the superior fundus uteri, using the cubital edge of the hand to sustain the tape while attempting to reach the middle part of the fundus uteri	Non-elastic tape measure	Superior fundus uteri to upper border of symphysis pubis
Kennedy (1979) *Botswana*	Measurement blinded to gestational age. Abdomen is divided into quarters above and below the umbilicus to more easily plot the position.	Tape measure	Fundus to symphysis pubis
Garde (1986) *South Africa*	Bladder must be empty. Upper curve of the fundus is seen by palpating both sides. Highest point is marked on the skin and checked with the index finger parallel to it, pushing backwards. Uterine fundus touches the lateral border of the finder when the mark is correctly placed. Distance is measured along the curve of the skin, without depressing it.	Tape measure	Highest point of fundus to the upper border of the symphysis pubis
Engstrom & Chen (1984; *USA*), Linasmita (1984; *Thailand*); Varney (1987; *USA*)	One end of the tape measure on the uppermost border of the symphysis pubis, then identify uppermost border of the uterine fundus and place the ulnar aspect of the other hand perpendicular to the long axis of the uterus. Bring tape measure over fundal hand and record fundal height at point where fundal hand intercepts the tape measure.	Tape measure	Uppermost point of the uterine fundus to upper border (or crest; Engstrom & Chen) of the symphysis pubis
Engstrom (1988) *USA*	Fingerbreadths are used in place of a tape measure to estimate centimeters above or below the selected landmark, or as a fraction of the distance between two landmarks (e.g. halfway or one-quarter of the way)	No instrument	Not specified
Euans (1995) *USA*	Palpate the uterine fundus, measurement made from symphysis to fundus, over the fetal axis, with relaxed abdominal and uterine musculature.	Tape measure face down	Symphysis pubis to fundus
Euans (1995) *USA*	Position the transducer at the superior aspect of the uterus so that the top of the fundus is visible on the imaging screen. Place a finger under the probe until its shadow coincides with the uppermost aspect of the uterus and mark this point on the abdomen. Distance from the superior aspect of the pubic symphysis to this point represents the true fundal height.	Ultrasound	Symphysis pubis to uppermost point of the uterus
Gardosi (1995) *UK*	Measure starting from the fundus to the symphysis pubis with the tape measure face down. Recommend serial plotting by the same observer.	Tape measure face down	Fundus to symphysis pubis
Caliper Technique—Internal			

(Continued)

Table 1. (Continued)

Author(s) of Technique	Description	Instrument	Upper to Lower Anatomic Landmarks
Country			
Ahlfeld: Internal Caliper (1871) *Germany*	Midline measurement with one branch of caliper is placed in maternal vagina against fetal head and other part of caliper in fetal pole of maternal uterus and obtain measurement of fetal axis	Pelvimetry Caliper	Uppermost point of uterine fundus to vagina against fetal head
Vogt (1922) *USA*	Index and middle fingers placed into the vagina against the fetal head. Measure the distance between the fetal buttocks in the uterine fundus and a specified point on the examining hand, and subtract the distance between that point on the examining hand and the tip of the fingers from the measurement.	Pelvimetry Caliper	Uterine fundus to fingers placed in vagina against fetal head
Poulos & Langstad (1953) *USA*	Same as Ahlfeld technique (different lower landmark); recommended to secure caliper with rubber band to examining hand	Pelvimetry Caliper	Uterine fundus to finger on fetal head through maternal rectum
Caliper Technique–External			
Ahlfeld: External Caliper (1871) *Germany*	One branch of caliper is placed 0.75 cm below the superior border of the symphysis pubis and the other branch of the caliper placed at the uppermost border of the fundus in the midline of the maternal abdomen.	External caliper	Uterine fundus to .75cm below the superior border of symphysis pubis
Reynolds & Baker (1951) *USA*	Similar to Ahlfeld technique (different lower landmark)	External caliper	Uterine fundus to inferior border of symphysis pubis
Poulos & Langstadt (1953)	Similar to Ahlfeld technique (different lower landmark)	External caliper	Uterine fundus to superior border of symphysis pubis

indicates that SFH in cm is equal to GA in weeks for weeks 16 through 32, and then increases by 1 cm every 2 weeks [34]. A "rule of four," referenced in the French Association of Gynecologists and Obstetricians syllabus for residents and commonly used in clinical practice in Rwanda, states that 4 should be added to SFH in cm to estimate GA in weeks (e.g., an SFH of 20 cm is equal to 24 weeks' gestation) [46]. The Global Network developed a color-coded SFH tape measure to classify pregnancies in one of three GA categories: red zone (24–36 weeks), yellow zone (<24 weeks) or green zone (>36 weeks), with different thresholds for Africa vs. Asia [47].

Statistical models have also been developed by many groups and investigators to estimate GA from single or serial SFH measurements (S2 Table in S1 Appendix) [44, 48–54]. White *et al.* developed an online calculator to estimate GA from SFH based on statistical modeling of serial SFH measures from a pregnancy cohort on the Thai-Myanmar border [54].

Population-based reference curves of the relationship between SFH and GA

We extracted data from studies that reported average or median SFH measurements for general obstetric populations in LMIC across weeks 20 to 40 of gestation. Nineteen unique studies (8 in Africa, 11 in Asia, 1 in South America) reported population-based reference values of SFH in LMIC [44, 47–65]. One study from Panama displayed graphs with 10% and 90% values, however did not display values or report on the 50% or mean and thus was not included [9]. Eight studies had ultrasound confirmed dating as the GA gold standard (Table 2) [44, 47, 50, 53, 54, 56, 61, 65] and 11 used LMP dating (S3 Table in S1 Appendix).

Accuracy of SFH to estimate GA

Ten studies comparing GA dating by SFH to a high quality gold standard of ultrasound-confirmed GA are shown in Table 3 [44, 45, 47, 53, 54, 66–70]. The range of the timing of SFH

Table 2. Population-based reference data of SFH measurements (cm) by ultrasound confirmed gestational age (weeks) dates in low-middle income countries.

Author & Year	Country & Study Setting	Sample size	Mean/ Median	20	22	24	26	28	30	32	33	34	35	36	37	38	39	40	41
African Studies																			
Althabe (2015)	Kinshasa, DRC	671	Median*♦			24.3	25.8	26.8	30.0	31.0	32.4	34.0	34.5	36.0					
Challis (2002)	Maputo, Mozambique	817	Mean*	19.0		23.0		26.8		30.0				33.0				35.0	
Kiserud (1986)	Arba Minch, Ethiopia	114	Mean (Curve)* †▽	18.2	19.7	22.0	23.7	25.8	27.5	29.4	30.2	31.0	31.8	32.7	33.4	33.8	34.2	34.6	34.9
Mador (2011)	Jos, Nigeria	405	Mean*†‡♦	18.9	22.5	23.9	25.6	28.2	29.8	31.9	32.8	33.4	33.9	35.7	36.7	38.3	38.1	39.1	
			Median♦	19.1	23.0	24.4	25.6	28.3	29.5	32.0	32.9	33.2	34.2	35.8	36.1	38.1	39.0	39.3	
Van Bogaert (1999)	Eastern Cape Province, South Africa	800	Mean (Curve)*	19.7	21.4	23.4	25.2	26.8	28.5	30.4	31.1	32.1	32.9	33.9	34.7	35.4	36.2	37.1	
Asian Studies																			
Althabe (2015)	Balgaum, India & Karachi, Pakistan	1089	Median*♦			22.5	24.0	26.0	28.0	30.0	30.5	31.3	32.5	32.3					
Lee (2020)	Sylhet, Bangladesh	1146	Mean*†♦	21.8	22.8	23.2	23.4	25.1	26.9	27.8	28.0	29.3	29.5	30.7	31.3	31.6	32.1	31.6	32.4
			Median♦	21.5	22.4	23.1	23.1	24.9	26.7	27.7	28.1	29.4	29.3	30.3	31.2	31.7	32.1	31.5	32.4
Rao (2014)	Sullia, India	100	Mean*	19.0		23.0		26.8		30.0				33.2				35.4	
White (2012)	Thailand, Maela refugee camp	2437	Mean (Curve)*	17.4	19.1	22.6	24.0	25.8	27.2	28.7	29.0	30.2	30.3	31.5	31.9	32.1	32.8	33.3	33.5

An empty cell indicates that the data was not available for that paper. Sample size was number of pregnant women in the study. Abbreviations: SFH = symphysis fundal height, GA = gestational age, DRC = Democratic Republic of Congo.

* Indicates inclusion in weighted population-based reference curve created in the current study (with shading in Mean/Median column; only Means from studies with ultrasound as the gold standard reference were included in the weighted population-based reference curve for this study)

† Indicates paper also has standard deviations for each gestational age week listed; ‡ Indicates paper also has standard error for each gestational age week listed

▽ Indicates study excluded preterm infants

♦ Indicates paper also has sample size (number of women) for each gestational age week listed

◊ Indicates population-based reference data study was presented in an inverted table (listed average weeks of gestational age for each whole SFH cm measurement).

** Pelotas, Brazil; Beijing, China; Nagpur, India; Turin, Italy; Nairobi, Kenya; Muscat, Oman; Oxford, UK; Seattle, USA; institutions providing obstetric care with no or low levels of major, known, non-microbiological contamination.

measures in pregnancy for each study is shown in S1 Table in S1 Appendix. Seven studies had an LMP reference are shown in appendix Table S4 in S1 Appendix [48, 52, 71–75].

Three studies reported upon the accuracy of GA estimated using the assumption that 1cm SFH is equal to 1 week of gestation, compared to ultrasound confirmed dating [44, 45, 70]. The precision error in the SFH GA estimate is reflected in the SD of the mean difference. In pooled analysis (n = 2,447 pregnancies), the mean difference between GA estimated by a single SFH measurement (1cm SFH = 1wk GA assumption) and ultrasound-confirmed GA was -14.0 days, with a pooled SD of 21.4 days (95% CI of ±42.8 days). This negative bias towards under-estimation of GA was likely strongly influenced by one study in Bangladesh, in which rates of SGA were high [44]. In sensitivity analysis excluding this study, the pooled mean bias was +1 day and was not significant.

We then assessed the accuracy of studies with a ultrasound-confirmed GA reference that used statistical models of SFH measures to predict GA. In the two studies (n = 1834 pregnancies) [44, 66] that used single measures of SFH to estimate GA, the mean bias was 0.0 and the precision error, or pooled SD, was 22.8 days, indicating that the statistical models predicted 95% of GA estimates within ±45.5 days of gold standard ultrasound/BOE dating. In statistical models that included three serial measurements of SFH during pregnancy to predict GA, the

Table 3. Studies reporting upon the accuracy of symphysis fundal height to estimate gestational age (higher quality studies with ultrasound-confirmed dating).

Author	Year	Study Setting (NICU/clinic/hospital/community, district/city, country)	Sample Size	SFH Measurement/conversion to GA	GA estimated by SFH versus BOE or LMP							Validity to identify preterm GA (<37 weeks unless otherwise noted)			
					Correlation (R) with reference GA	Mean difference/bias (days) (SFH – reference GA)	SD of the mean GA difference (days)	Bland Altman 95% LOA (LL, UL) [days]	95% CI prediction error	% within 7 days	% within 14 days	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Althabe	2015	1) Argentina; 2) India 3) Pakistan; 4) Zambia	1029	Color coded tape	–			–	–	–	–	<36wk 1)87; 2)78 3) 63; 4)91	<36wk 1)51; 2)89 3) 94; 4)50	–	–
White	2012	Antenatal clinic, Thai-Burmese border	2437	Statistical model, 3 measures	–	–	16.6*	–	(-36, 29)	–	62	–	–	–	–
van Rensburg	2003	Primary health center, Bloemfontein, South Africa	173	SFH cm = GA wk	–	-11.2	17.6*	(-23.4, 45.8)	–	–	59	–	–	–	–
Karl	2015	Primary health centers, Madang, PNG	688	Linear-White model	0.49	0	–	(-26, 26)	–	–	–	72	87	23	98
			502	Sequential-White model	0.21	4	11.5*	(-19, 26)	–	–	–	43	96	40	97
Malaba	2018	Primary center, S Africa	261	NS	–	–	–	–	–	36% concordance[1]	–	–	–	–	–
Moore	2015	Clinic, Thai-Myanmar	704	White model, 3 measures	–	1.12	7.42	–	–	–	–	21	99	–	–
Jehan	2010	Community-based, Hyderabad, Pakistan	1128	SFH cm = GA wk	–	3.08	11.9	–	–	75	91	67.8	95.8	77.6	93.3
Lee	2020	Community-based, Sylhet district, Bangladesh	1486	SFH cm = GA wk		-30.8	28.2*	(-87, 26)	–			<34wk 83;	<34wk 71;	<34wk 80.8;	<34wk 73.2;
				Model, 1 measure	0.70	–	26.9*	–	+/- 53.3	–	40	<37wk	<37wk	<37wk	<37wk
				Model, 3 measures	0.71	–	25.9*	–	+/- 51.7	–	69	81	67	88.2	53.7
van Bogaert	1999	Tertiary hospital, Eastern Cape Province, S. Africa	800	NS	0.91	–	–	–	–	–	–	–	–	–	–

(Continued)

Table 3. (Continued)

Author	Year	Study Setting (NICU/clinic/hospital/community, district/city, country)	Sample Size	SFH Measurement/conversion to GA	Correlation (R) with reference GA	GA estimated by SFH versus BOE or LMP						Validity to identify preterm GA (<37 weeks unless otherwise noted)			
						Mean difference/bias (days) (SFH—reference GA)	SD of the mean GA difference (days)	Bland Altman 95% LOA (LL, UL) [days]	95% CI prediction error	% within 7 days	% within 14 days	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Shrestha	2017	Banke District, Nepal	614	NS	0.40	–	–	–	–	19	62	–	–	–	–

(–) indicates that the data was not available for that paper

*Numbers were calculated by authors of this paper

[1]Concordance defined by American College of Obstetricians and Gynecologists: <7 days between 14–15 weeks, <10 days between 16–21 weeks, and <14 days between 22–27 weeks

Abbreviations: SFH = symphysis fundal height, NS = not stated, GA = gestational age, AGA = appropriate-size-for-gestational age, SD = standard deviation, LOA = limits of agreement, LL = lower limit, UL = upper limit, CI = confidence interval, PPV = positive predictive value, NPV = negative predictive value, BOE = BOE, LMP = last menstrual period

https://doi.org/10.1371/journal.pone.0272718.t003

precision error was improved. Based on four studies (n = 4391 pregnancies), GA estimation using three serial SFH measurements had a mean bias of -1.9 days and pooled SD of 17.1 days, with a 95% prediction window for GA of ±33.4 days [44, 54, 66, 68]. In sensitivity analysis excluding the Bangladesh study [44], the pooled SD was 14.6 days, with a 95% prediction window of ±29.6 days.

Several studies reported the percentage of pregnancies that would be dated by SFH within ±7 days or ±14 days of ultrasound dating. Compared to ultrasound-confirmed GA, SFH-based dates were within ±7 days for 19% [69] to 75% [45] of pregnancies in two studies. The percentage of pregnancies that would be dated by SFH within ±14 days of ultrasound dating ranged from 40% to 91% in five studies [44, 45, 54, 69, 70]. In a pooled analysis of these five studies (n = 5838 pregnancies), an estimated 71% (95% CI: 66–77%) of pregnancies were dated within ±14 days of ultrasound confirmed dating.

Nine studies reported Pearson correlation coefficients for GA estimated by SFH compared to GA estimated by a gold standard technique. Compared to ultrasound, correlation coefficients ranged from 0.21 to 0.91 (median 0.55; n = 4 studies) [44, 53, 66, 69].

Accuracy of SFH to identify preterm gestational age

Several studies in this review had also assessed the diagnostic accuracy of SFH to identify preterm GA at varying thresholds of GA (Table 3). Data were not pooled because of the wide range of thresholds for preterm GA as well as cut-off values of SFH to identify preterm GA.

In the multi-country Antenatal Corticosteroids Trial (ACT), the National Institute of Child Health and Human Development (NICHD) Global Network used a cut-off of the mean 10th percentile of SFH measures at the 36th week of completed gestation based on regional population-based data to estimate the sensitivity and specificity of the SFH cut-off to classify prematurity (<36 weeks). The cut-off performed better in India (78% sensitivity, 89% specificity) and Pakistan (63% sensitivity, 94% specificity) than in Argentina (87% sensitivity, 51% specificity) and Zambia (91% sensitivity, 50% specificity) [76].

Four studies assessed the validity of SFH cut-offs to identify prematurity <37 weeks. In one study, using the 1cm = 1wk GA clinical assumption had a sensitivity of 68% and a specificity of 96% [45]. Karl et al. calculated the sensitivity and specificity of statistical models using a single SFH measure as well as three serial SFH measures to predict preterm GA (<37 weeks) [66]. A single SFH measurement had a sensitivity of 72% and specificity of 87% to predict preterm birth, while three serial SFH measurements had 43% sensitivity and 96% specificity. Similar to Karl et al., Moore et al. reported low sensitivity (21%) and high specificity (99%) for preterm classification by three serial SFH measurements compared to early ultrasound, with misclassification of 79% of preterm newborns as term [68]. Lee et al. reported that an SFH cut-off of <30 cm had 81% sensitivity and 67% specificity for classification of preterm GA <37 weeks, and that an SFH cut-off of <29 cm had 83% sensitivity and 71% specificity for classification of preterm GA <34 weeks, which is the threshold for providing antenatal corticosteroids [44].

Inter- and intra-rater reliability of SFH measurements

Ten studies had at least 50 subjects for inter-rater and/or intra-rater reliability assessments (S4 Table in S1 Appendix). For inter-rater reliability, the mean difference between measurers was reported to be 0.66 cm (SD ±1 cm) [77], 0.88 cm (95% LOA ±3.65 cm) [44], and 2.06 cm [78]. Rogers et al. and Lee et al. reported that 95% and 70% of measurements, respectively, between two measurers were within 2 cm of each other, and Althabe et al. reported that 95% of measurements between two measurers were within 2–3 cm [44, 47, 77]. For intra-rater reliability, Papageorghiou et al. reported that the mean difference between two SFH measurements by the

same measurer was 0.07 cm with 95% LOA of 1.5 cm [2], and Engstrom *et al*. reported a mean difference of 1.13 cm [78] between measurements by the same measurer.

Discussion

Main findings

In our systematic review, we identified a wide range of techniques to measure SFH (Table 1) and methods by which to calculate GA from SFH measurements, and highly variable inter-rater reproducibility of measurements (S2 Table in S1 Appendix). Based on our pooled analysis, the common clinical assumption that 1 cm SFH is equal to 1 week of gestation dated pregnancies with a wide margin of error of ±43 days compared to ultrasound or best obstetric estimate based dating. Statistical models using three serial SFH measurements performed somewhat better, dating 95% of pregnancies within ±33 days of ultrasound or BOE based GA estimates.

Strengths & limitations

To our knowledge, this is one of the few reports to systematically examine and report upon the use of SFH for the purpose of GA dating (as opposed to monitoring or identification of fetal growth restriction), and specifically in LMIC settings where SFH is used for this purpose given limited access to more accurate GA methods like ultrasound. It is in these very settings where rates of pregnancy morbidity and fetal growth restriction are high, and thus SFH to GA conversion methods based on highly-selective study populations and optimal fetal growth would systematically underestimate many pregnancies in LMIC. We extensively searched a range of databases and gray literature to identify potential data sources. A wide range of measurement techniques are summarized, as well as conversion methods to translate an SFH measurement to a GA. We describe 37 studies across 5 regions, with 33,346 study participants, and summarize 19 different measuring techniques and 12 different ways clinicians/ researchers have converted SFH into GA.

The study quality for a majority of studies was low, as many did not clearly describe the technique of SFH measurement or the method used to calculate gestational age from SFH. Forty-one percent of studies did not have a high-quality gold standard dating method (ultrasound or best obstetric estimate including ultrasound). Additionally, while a common clinical algorithm is the use of a combination of measures to estimate GA, such as SFH in combination with LMP, we did not have adequate data to assess the accuracy of combined methods. Data availability within the parameters of our inclusion criteria was a limitation for analysis. Additionally, although the studies included in our analyses had ultrasound-confirmed dates as the reference standard, different SFH measuring techniques, SFH to GA conversion methods, and studying sampling methods were used.

Interpretation in light of other evidence

The accuracy of using SFH to estimate GA has long been debated, however SFH continues to be used in LMIC for GA dating due to the lack of other routinely available and feasible methods for GA determination. Based on our findings, SFH should not be used as the sole method of determining GA because SFH estimates of GA were quite inaccurate compared to ultrasound confirmed dating, with a wide margin of error.

The recent publication of the results of the WHO Antenatal Corticosteroids for Improving Outcomes in preterm Newborns (ACTION) Trial underscores the importance of using accurate GA dating methods like ultrasound instead of SFH for clinical decision-making to manage

preterm birth [79]. The previous Global Network's Antenatal Corticosteroids Trial—which used LMP or SFH as the basis for identifying women at risk of preterm labor for targeted administration of dexamethasone—failed to show benefits among small infants (<5th percentile for birth weight, the trial's proxy for preterm) and was associated with an overall increase in neonatal mortality, stillbirth, and suspected maternal infection in the intervention group [80]. The inaccuracy of GA determination by LMP and SFH was considered to be a potential reason for these unexpected findings as there may have been inclusion of term but growth-restricted fetuses in the trial [81]. As a result of the Global Network Trial, in 2015 the WHO recommended that antenatal corticosteroids be used only under certain conditions, including the accurate assessment of GA by early ultrasound. When ultrasound was used to determine GA and identify women at risk of preterm birth in the WHO ACTION Trial for corticosteroid treatment, dexamethasone was associated with significant reductions in neonatal death, and stillbirth compared to placebo [79].

Therefore, our recommendations are to minimize or even eliminate the role of SFH in GA estimation during clinical antenatal care and research, and to instead prioritize increasing coverage of early ultrasound as well as training in ultrasonography in LMIC. Expanding access to ultrasound would ensure that pregnancy monitoring and delivery of life-saving interventions like antenatal corticosteroids are guided by accurate estimation of gestational age.

Several important studies reported data on the relationship between SFH and gestational age but were excluded from the review but are detailed in supplementary materials. (S1 Table in S1 Appendix) Because these study cohorts were aimed to develop standards for optimal fetal growth and were restricted to healthy, low-risk women without pregnancy morbidities; the relationships between GA and SFH in these studies would not be generalizable to general obstetric populations in LMICs. With the aim of creating global prescriptive SFH "standards" for fetal growth monitoring, the INTERGROWTH-21st study, and growth standards for SFH [2], applied rigorous selection criteria that excluded pregnancies with known socioeconomic and health constraints on fetal growth. The study excluded women of low and high BMI and women with significant comorbidities who comprise a large proportion of pregnancies in LMICs. In an indigenous pregnant population in Panama [9] with high rates of UTI, hookworm, and undernutrition, the prevalence of SFH <10% according to the INTERGROWTH standard was 50.6%, compared to 8% using the local SFH reference. If the gestational age is known, use of INTERGROWTH-21st SFH charts would flag pregnancies with suspected fetal growth restriction in these settings. However, if accurate GA is not known and SFH is used to establish GA rather than screen for growth abnormalities, use of INTERGROWTH-21st SFH standards would systematically underestimate GA when applied to general obstetric populations such as this or in Asia, where fetal growth restriction or pregnancy morbidities are prevalent [2, 8]. SFH measurement appears to be more accurate for GA estimation when the study populations are selected for optimal fetal growth as the assumption that size is equivalent to age is more likely to be valid. For example, the agreement between SFH and ultrasound-based GA was relatively higher in the NICHD Fetal Growth Study, that enrolled only pregnant women with pregravid BMI 19–29.9 kg/m2, without pre-existing medical diagnoses or pregnancy diseases (gestational diabetes, pre-eclampsia) [1]. However, we excluded such studies from our analysis on accuracy of SFH for GA estimation to reflect real-world conditions and have highlighted how poor SFH performs in the general obstetric population in LMICs.

The variation in the definition of SFH and how it is measured contributes to a body of literature in which researchers and practitioners are measuring different things, in different ways, and interpreting their measurements differently. We identified 19 different SFH measurement techniques (Table 1) and 12 different ways in which clinicians/researchers have converted

SFH to gestational age (S2 Table in S1 Appendix), ranging from simple rules like McDonald's "1 to 1" rule to complex regression equations. Inter-rater reproducibility of measurements is also highly variable across studies. Many dynamic factors increase variability, including transverse and oblique fetal lies, Braxton Hicks contractions, the fullness of the woman's bladder, and fetal movements [82]. It is therefore unsurprising that, based on our systematic review, the limits of agreement for SFH are wide compared to gold standard GA estimates and that inter- and intra-observation variation is high. Other factors may influence SFH measurement that we were not able to address in this review, including maternal obesity [1, 67, 73] and timing in pregnancy of SFH measurements [1].

Conclusion

Accurate estimates of GA are needed for safe and effective antenatal care, including fetal growth monitoring and decision-making about interventions for high-risk pregnancies. Our systematic review and meta-analysis assessing the agreement between SFH and ultrasound-confirmed pregnancy dating found that SFH had wide margins of error, which we feel are unacceptably wide to be clinically relevant. Furthermore, there needs to be greater awareness of the existing variability in SFH definitions, measuring techniques, and conversions, which further comprises clinical utility for GA dating. Even though it is often the only method used or available, SFH measurement has low accuracy and may not be possible to improve. This study underscores the importance of improving coverage of early pregnancy ultrasound scans and new ultrasound techniques to improve GA assessment in late pregnancy.

Supporting information

S1 Checklist. PRISMA 2009 checklist.
(DOCX)

S1 Appendix.
(DOCX)

Acknowledgments

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References

1.   Pugh SJ, Ortega-Villa AM, Grobman W, Newman RB, Owen J, Wing DA, et al. Estimating gestational age at birth from fundal height and additional anthropometrics: a prospective cohort study. BJOG: An International Journal of Obstetrics & Gynaecology. 2018; 125(11):1397–404. https://doi.org/10.1111/1471-0528.15179 PMID: 29473290

2.   Papageorghiou AT, Ohuma EO, Gravett MG, Hirst J, da Silveira MF, Lambert A, et al. International standards for symphysis-fundal height based on serial measurements from the Fetal Growth Longitudinal Study of the INTERGROWTH-21st Project: prospective cohort study in eight countries. BMJ (Clinical research ed). 2016; 355. https://doi.org/10.1136/bmj.i5662 PMID: 27821614

3.   Scott K, Gupta S, Williams E, Arthur M, Somayajulu UV, Noguchi L. "I can guess the month. . . but beyond that, I can't tell" an exploratory qualitative study of health care provider perspectives on gestational age estimation in Rajasthan, India. BMC pregnancy and childbirth. 2020; 20(1):1–13. https://doi.org/10.1186/s12884-020-03201-6 PMID: 32917163

4.   Althabe F, Belizán JM, Buekens P, McClure EM, Koso-thomas M, Committee NsGNfWs, et al. Antenatal corticosteroids to reduce preterm deaths in low-income settings. The Lancet Global health. 2014; 2 (8):e444. Epub 2014/07/23. https://doi.org/10.1016/S2214-109X(14)70261-X PMID: 25103510; PubMed Central PMCID: PMC4767156.

5.   Fung R, Villar J, Dashti A, Ismail LC, Staines-Urias E, Ohuma EO, et al. Achieving accurate estimates of fetal gestational age and personalised predictions of fetal growth based on data from an international prospective cohort study: a population-based machine learning study. Lancet Digit Health. 2020; 2(7): e368–e75. Epub 2020/06/23. https://doi.org/10.1016/S2589-7500(20)30131-X PMID: 32617525; PubMed Central PMCID: PMC7323599.

6.   Performance of late pregnancy biometry for gestational age dating in low-income and middle-income countries: a prospective, multicountry, population-based cohort study from the WHO Alliance for Maternal and Newborn Health Improvement (AMANHI) Study Group. The Lancet Global health. 2020; 8(4): e545–e54. Epub 2020/03/22. https://doi.org/10.1016/S2214-109X(20)30034-6 PMID: 32199122; PubMed Central PMCID: PMC7091029.

7.   Self A, Daher L, Schlussel M, Roberts N, Ioannou C, Papageorghiou AT. Second and third trimester estimation of gestational age using ultrasound or maternal symphysis-fundal height measurements: A systematic review. BJOG: an international journal of obstetrics and gynaecology. 2022. Epub 2022/02/15. https://doi.org/10.1111/1471-0528.17123 PMID: 35157348.

8.   Nardozza LMM, Júnior EA, Rizzo G, Deter RL. Fetal Growth Restriction: Current Evidence and Clinical Practice: Springer; 2018.

9.   González-Fernández D, Nemeth E, Pons EdC, Rueda D, Sinisterra OT, Murillo E, et al. INTERGROWTH-21 Identifies High Prevalence of Low Symphysis–Fundal Height in Indigenous Pregnant Women Experiencing Multiple Infections, Nutrient Deficiencies, and Inflammation: The Maternal Infections, Nutrient Deficiencies, and Inflammation (MINDI) Cohort. Curr Dev Nutr. 2021; 5(4):nzab012. https://doi.org/10.1093/cdn/nzab012 PMID: 33898918

10. Bryce E, Gurung S, Tong H, Katz J, Lee AC, Black RE, et al. Population attributable fractions for risk factors for spontaneous preterm births in 81 low- and middle-income countries: A systematic analysis. Journal of global health. 2022; 12:04013. Epub 2022/04/01. https://doi.org/10.7189/jogh.12.04013 PMID: 35356651; PubMed Central PMCID: PMC8959104 Form (available upon request from the corresponding author), and declare no conflicts of interest.

11. Abalos E, Chamillard M, Diaz V, Tuncalp Ö, Gülmezoglu AM. Antenatal care for healthy pregnant women: a mapping of interventions from existing guidelines to inform the development of new WHO guidance on antenatal care. BJOG: An International Journal of Obstetrics & Gynaecology. 2016; 123 (4):519–28. https://doi.org/10.1111/1471-0528.13820 PMID: 26694196

12. Goto E. Prediction of low birthweight and small for gestational age from symphysis-fundal height mainly in developing countries: a meta-analysis. Journal of epidemiology and community health. 2013; 67 (12):999–1005. Epub 2013/07/16. https://doi.org/10.1136/jech-2012-202141 Epub 2013 Jul 13. PMID: 23851150.

13. Pay ASD, Wiik J, Backe B, Jacobsson B, Strandell A, Klovning A. Symphysis-fundus height measurement to predict small-for-gestational-age status at birth: A systematic review. BMC Pregnancy and Childbirth. 2015; 15(1). https://doi.org/10.1186/s12884-015-0461-z PMID: 25884884

14. Neilson JP. Symphysis-fundal height measurement in pregnancy. Cochrane Database of Systematic Reviews. 2008;(1). CD000944.

15. Robert Peter J. Symphysial fundal height (SFH) measurement in pregnancy for detecting abnormal fetal growth. Cochrane Database of Systematic Reviews. 2015;(9). CD008136. https://doi.org/10.1002/14651858.CD008136.pub3 PMID: 26346107

16. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. Jama. 2000; 283(15):2008–12. Epub 2000/05/02. https://doi.org/10.1001/jama.283.15.2008 PMID: 10789670.

17. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009; 6(7):e1000097. Epub 2009/07/22. https://doi.org/10.1371/journal.pmed.1000097 PMID: 19621072; PubMed Central PMCID: PMC2707599.

18. Bank TW. How does the World Bank classify countries? [Nov 10, 2020]. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries.

19. Whiting PF, Rutjes AW, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, et al. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. Ann Intern Med. 2011; 155(8):529–36. Epub 2011/10/19. https://doi.org/10.7326/0003-4819-155-8-201110180-00009 PMID: 22007046.

20. Lee AC, Katz J, Blencowe H, Cousens S, Kozuki N, Vogel JP, et al. National and regional estimates of term and preterm babies born small for gestational age in 138 low-income and middle-income countries in 2010. The Lancet Global health. 2013; 1(1):e26–36. Epub 2014/08/12. https://doi.org/10.1016/S2214-109X(13)70006-8 PMID: 25103583; PubMed Central PMCID: PMC4221634.

21. Rosner B. Fundamentals of biostatistics: Cengage learning; 2015.

22. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al. Cochrane handbook for systematic reviews of interventions: John Wiley & Sons; 2019.

23. Ahlfeld F. Bestimmungen der Grösse und des Alters der Frucht vor der Geburt. Archiv für Gynäkologie. 1871; 2(3):353–72. https://doi.org/10.1007/bf01937160

24. Belizan JM, Villar J, Nardin JC, Malamud J, De Vicurna LS. Diagnosis of intrauterine growth retardation by a simple clinical method: measurement of uterine height. Am J Obstet Gynecol. 1978; 131(6):643–6. Epub 1978/07/15. https://doi.org/10.1016/0002-9378(78)90824-4 PMID: 686050.

25. Engstrom JL. Measurement of fundal height. Journal of obstetric, gynecologic, and neonatal nursing: JOGNN. 1988; 17(3):172–8. Epub 1988/05/01. https://doi.org/10.1111/j.1552-6909.1988.tb00422.x PMID: 3292729.

26. Engstrom JL, Chen EH. Prediction of birthweight by the use of extrauterine measurements during labor. Research in Nursing & Health. 1984; 7(4):314–23. https://doi.org/10.1002/nur.4770070410 PMID: 6570061

27. Euans DW, Connor PD, Hahn RG, Rodney Wm M, Arheart KL. A comparison of manual and ultrasound measurements of fundal height. Journal of Family Practice. 1995; 40(3):233–6. PMID: 7876779

28. Garde PM. Growth rate score to screen for intrauterine growth retardation. Tropical Doctor. 1986; 16(2):71–4. 161634. https://doi.org/10.1177/004947558601600211 PMID: 3765083

29. Gardosi JO, Mongelli JM, Mul T. Intrauterine growth retardation. Baillieres Clin Obstet Gynaecol. 1995; 9(3):445–63. https://doi.org/10.1016/s0950-3552(05)80374-8 PMID: 8846549.

30. Willson CBIF J., et al. Obstetrics and Gynecology. First ed. St. Louis: Mosby; 1958.

31. Kennedy I, Stephens B. A novel antenatal record to help midwives. Practitioner. 1979; 223(1333):18–24. PMID: 482243.

32. Linasmita V, Sugkraroek P. Normal uterine growth curve by measurement of symphysial-fundal height in pregnant women seen at Ramathibodi Hospital. Journal of the Medical Association of Thailand = Chotmaihet thangphaet. 1984; 67 Suppl 2:22–6. Epub 1984/10/01. PMID: 6512455.

33. McDonald E. Mensuration of the Child in the Uterus with New Methods. Journal of the American Medical Association. 1906; 47(24):1979–83.

34. McDonald E. The Duration of Pregnancy, with a New Rule For its Estimation. The American Journal of the Medical Sciences (1827–1924). 1910; 140(3):349.

35. Poulos PP, Langstadt JR. The volume of the uterus during labor and its correlation with birth weight. I. A method for the prediction of birth weight. Am J Obstet Gynecol. 1953; 65(2):233–44. https://doi.org/10.1016/0002-9378(53)90423-2 PMID: 13040372.

36. Reynolds SRM, Baker JT. Effect of parity in women on the pattern of uterine enlargement during the latter half of gestation: Carnegie Institution; 1951.

37. Spalding AB. The Value of Abdominal Measurements in Pregnancy: A Statistical Study. Journal of the American Medical Association. 1913; 61(10):746–9. https://doi.org/10.1001/jama.1913.04350100024008

38. Spiegelberg O. De cervicis uteri in graviditate mutationibus earumque qusad diagnosin zestimatione1865.

39. Spiegelberg O, Hurry JB. A text book of midwifery. London: The New Sydenham Society; 1887. 2 v. p.

40. Varney H. Nurse Midwifery 2e: Wiley-Blackwell; 1987.

41. Vogt W. The interruption of pregnancy at term with a consideration of the methods of estimating the maturity of the fetus in utero. Southern Medical Journal. 1922; 15(4):290–6.

42. Westin B. Gravidogram and fetal growth. Comparison with biochemical supervision. Acta Obstet Gynecol Scand. 1977; 56(4):273–82. https://doi.org/10.3109/00016347709154978 PMID: 602692.

43. Engstrom JL, Sittler CP. Fundal height measurement. Part 1—Techniques for measuring fundal height. J Nurse Midwifery. 1993; 38(1):5–16. https://doi.org/10.1016/0091-2182(93)90120-6 PMID: 8423493.

44. Lee ACC, Whelan R, Bably NN, Schaeffer LE, Rahman S, Ahmed S, et al. Prediction of gestational age with symphysis-fundal height and estimated uterine volume in a pregnancy cohort in Sylhet, Bangladesh. BMJ open. 2020; 10(3):e034942. Epub 2020/03/12. https://doi.org/10.1136/bmjopen-2019-034942 PMID: 32169927; PubMed Central PMCID: PMC7069288.

45. Jehan I, Zaidi S, Rizvi S, Mobeen N, McClure EM, Munoz B, et al. Dating gestational age by last menstrual period, symphysis-fundal height, and ultrasound in urban Pakistan. Int J Gynaecol Obstet. 2010; 110(3):231–4. Epub 2010/06/12. https://doi.org/10.1016/j.ijgo.2010.03.030 PMID: 20537328; PubMed Central PMCID: PMC2914118.

46. Fournié A, Lefebvre-Lacoeuille C, Cotici V, Harif M, Descamps P. The fundal height measurements in single pregnancies and the detection of fetal growth retardation. J Gynecol Obstet Biol Reprod (Paris). 2007; 36(7):625–30. Epub 2007/03/06. https://doi.org/10.1016/j.jgyn.2007.01.011 Epub 2007 Mar 1. PMID: 17335998.

47. Althabe F, Berrueta M, Hemingway-Foday J, Mazzoni A, Bonorino CA, Gowdak A, et al. A color-coded tape for uterine height measurement: A tool to identify preterm pregnancies in low resource settings. PLoS ONE. 2015; 10(3). https://doi.org/10.1371/journal.pone.0117134 PMID: 25822529

48. da Cunha SP, Ribeiro JU, Berezowski AT, Duarte G. Evolution of uterine height and abdominal circumference in normal pregnant women. Revista paulista de medicina. 1985; 103(5):231–4.

49. Deeluea J, Sirichotiyakul S, Weerakiet S, Buntha R, Tawichasri C, Patumanond J. Fundal height growth curve for Thai women. ISRN Obstetrics and Gynecology. 2013; 2013. https://doi.org/10.1155/2013/463598 PMID: 23691342

50. Mador E, Pam S, Pam I, Mutihir J, Adoga G, Ogunranti J. Symphysio-Fundal Height Nomogram In Ultrasound Dated Pregnancies. Asian Journal of Medical Sciences. 2011; 1. https://doi.org/10.3126/ajms.v1i2.3138

51. Ogunranti JO. Fundal height in normal pregnant Nigerian women: anthropometric gravidogram. Int J Gynaecol Obstet. 1990; 33(4):299–305. https://doi.org/10.1016/0020-7292(90)90514-l PMID: 1979282.

52. Sogbanmu MO. Simple method of assessment of fetal maturity in a rural community in Nigeria. East Afr Med J. 1980; 57(5):346–9. Epub 1980/05/01. PMID: 7398551.

53. van Bogaert LJ. Customised gravidogram and fetal growth chart in a South African population. Int J Gynaecol Obstet. 1999; 66(2):129–36. Epub 1999/09/01. https://doi.org/10.1016/s0020-7292(99)00068-5 PMID: 10468335.

54. White LJ, Lee SJ, Stepniewska K, Simpson JA, Dwell SLM, Arunjerdja R, et al. Estimation of gestational age from fundal height: A solution for resource-poor settings. Journal of the Royal Society Interface. 2012; 9(68):503–10. https://doi.org/10.1098/rsif.2011.0376 PMID: 21849388

55. Agarwal S, Agarwal A, Bansal AK, Agarwal DK, Agarwal KN. Birth weight patterns in rural undernourished pregnant women. Indian pediatrics. 2002; 39(3):244–53. Epub 2002/03/23. PMID: 11910133.

56. Challis K, Osman NB, Nystrom L, Nordahl G, Bergstrom S. Symphysis-fundal height growth chart of an obstetric cohort of 817 Mozambican women with ultrasound-dated singleton pregnancies. Tropical medicine & international health: TM & IH. 2002; 7(8):678–84. https://doi.org/10.1046/j.1365-3156.2002.00907.x PMID: 12167094.

57. Ebite LE, Ebeigbe PN, Igbigbi P, Akpuaka FC. Symphysiofundal height growth curve and growth velocity in pregnant women in a Nigerian community. Journal of Obstetrics and Gynaecology. 2009; 29(7):605–8. https://doi.org/10.1080/01443610903118254 PMID: 19757263

58. Fikree F, De Onis M, Marshall P, Badrudding S, Bryant J, Berendes H, et al. A rapid nutritional evaluation of pregnant women in urban areas in developing countries. [Unpublished] [1988]. 1988.

59. Ghate M, Pratinidhi A, Gupte A. Risk prediction charts for low birth weight. Indian pediatrics. 1996; 33(1):15–8. Epub 1996/01/01. PMID: 8772945.

60. Indira R, Oumachigui A, Narayan KA, Rajaram P, Ramalingam G. Symphysis-fundal height measurement—A reliable parameter for assessment of fetal growth. International Journal of Gynecology and Obstetrics. 1990; 33(1):1–5. https://doi.org/10.1016/0020-7292(90)90646-3 PMID: 1974525

61. Kiserud T. Fundal height growth in rural Africa. Acta Obstet Gynecol Scand. 1986; 65(7):713–5. Epub 1986/01/01. https://doi.org/10.3109/00016348609161487 PMID: 3544659.

62. Mathai M, Jairaj P, Muthurathnam S. Screening for light-for-gestational age infants: a comparison of three simple measurements. Br J Obstet Gynaecol. 1987; 94(3):217–21. Epub 1987/03/01. https://doi.org/10.1111/j.1471-0528.1987.tb02357.x PMID: 3567117.

63. Papageorghiou AT, Kemp B, Stones W, Ohuma EO, Kennedy SH, Purwar M, et al. Ultrasound-based gestational-age estimation in late pregnancy. Ultrasound in Obstetrics & Gynecology. 2016; 48(6):719–26. https://doi.org/10.1002/uog.15894 PMID: 26924421

64. Ulstein M, Rana G, Yangzom K, Gurung R, Karki A, Gurung G, et al. Some fetal and pregnancy parameters in Nepal. Acta Obstet Gynecol Scand. 1988; 67(1):47–52. Epub 1988/01/01. https://doi.org/10.3109/00016348809004167 PMID: 3176914.

65. Rao T, Doppa G, Gowder R, editors. Case Study—Is There a Need to Customize Gravidogram Based on Ethnic Population? [Poster]. RCOG World Congress; 2014.

66. Karl S, Li Wai Suen CSN, Unger HW, Ome-Kaius M, Mola G, White L, et al. Preterm or not—An evaluation of estimates of gestational age in a cohort of women from rural Papua New Guinea. PLoS ONE. 2015; 10(5). https://doi.org/10.1371/Journal.pone.0124286 PMID: 25945927

67. Malaba TR, Newell ML, Madlala H, Perez A, Gray C, Myer L. Methods of gestational age assessment influence the observed association between antiretroviral therapy exposure, preterm delivery, and small-for-gestational age infants: a prospective study in Cape Town, South Africa. Ann Epidemiol. 2018; 28(12):893–900. Epub 2018/08/29. https://doi.org/10.1016/j.annepidem.2018.08.011 PMID: 30293920; PubMed Central PMCID: PMC6286247.

68. Moore KA, Simpson JA, Thomas KH, Rijken MJ, White LJ, Dwell SLM, et al. Estimating Gestational Age in Late Presenters to Antenatal Care in a Resource-Limited Setting on the Thai-Myanmar Border. Plos One. 2015; 10(6). https://doi.org/10.1371/journal.pone.0131025 WOS:000358147500122. PMID: 26114295

69. Shrestha R, Andrews-Trevino JY, Acharya S, Lamichhane A, Pokharel A, Davis D, et al. Estimating gestational age using last menstrual period (LMP) and symphysis fundal height (SFH) measures rather than ultrasound examination: A test of methods for use in low income settings. Annals of Nutrition and Metabolism. 2017; 71:762–3. https://doi.org/10.1159/000480486

70. van Rensburg YJ, Botha D, Nel R, Fichardt A. A comparison of skilled methods to determine gestational age in pregnancy. Curationis. 2003; 26(1):22–6.

71. Adewale FB, Ijaiya MA. Symphysio-fundal height measurement as a means of gestational age assessment in the second half of pregnancy at the University of Ilorin Teaching Hospital, Nigeria. Bangladesh Journal of Obstetrics and Gynecology. 2011; 26(1):3–9.

72. Amagloh FK, Williams AA, Angbing I. Evaluation of some maternal and socio-economic factors associated with low birthweight among women in the Upper East Region, Ghana. African Journal of Food Agriculture Nutrition and Development. 2009; 9(7):1498–510. https://doi.org/10.1016/0027-5107(77)90246-9 PMID: 339077.

73. Baeyertz JD. Assessment of gestational maturity using a new fundal height measuring tape. The New Zealand medical journal. 1983; 96(746):1059–60. Epub 1983/12/28. PMID: 6581413.

74. Jimenez JM, Tyson JE, Reisch JS. Clinical measures of gestational age in normal pregnancies. Obstet Gynecol. 1983; 61(4):438–43. Epub 1983/04/01. PMID: 6828273.

75. Rada S, Gamper J, González R, Mombo-Ngoma G, Ouédraogo S, Kakolwa MA, et al. Concordance of three alternative gestational age assessments for pregnant women from four African countries: A secondary analysis of the MIPPAD trial. PloS one. 2018; 13(8):e0199243. https://doi.org/10.1371/journal.pone.0199243 PMID: 30080869

76. Althabe F, Belizán JM, Mazzoni A, Berrueta M, Hemingway-Foday J, Koso-Thomas M, et al. Antenatal corticosteroids trial in preterm births to increase neonatal survival in developing countries: Study protocol. Reproductive health. 2012; 9(1). https://doi.org/10.1186/1742-4755-9-22 PMID: 22992312

77. Rogers MS, Chan E, Ho A. Fundal height: Does prior knowledge of gestational age influence the measurement? Journal of Obstetrics and Gynaecology. 1992; 12(1):4–5.

78. Engstrom JL, McFarlin BL, Sittler CP. Fundal height measurement. Part 2—Intra- and interexaminer reliability of three measurement techniques. J Nurse Midwifery. 1993; 38(1):17–22. https://doi.org/10.1016/0091-2182(93)90121-v PMID: 8423487.

79. Oladapo OT, Vogel JP, Piaggio G, Nguyen MH, Althabe F, Gülmezoglu AM, et al. Antenatal Dexamethasone for Early Preterm Birth in Low-Resource Countries. N Engl J Med. 2020. Epub 2020/10/23. https://doi.org/10.1056/NEJMoa2022398 PMID: 33095526.

80. Althabe F, Belizan JM, McClure EM, Hemingway-Foday J, Berrueta M, Mazzoni A, et al. A population-based, multifaceted strategy to implement antenatal corticosteroid treatment versus standard care for the reduction of neonatal mortality due to preterm birth in low-income and middle-income countries: the ACT cluster-randomised trial. Lancet (London, England). 2015; 385(9968):629–39. https://doi.org/10.1016/S0140-6736(14)61651-2 PMID: 25458726; PubMed Central PMCID: PMC4420619.

81. McClure EM, Goldenberg RL, Jobe AH, Miodovnik M, Koso-Thomas M, Buekens P, et al. Reducing neonatal mortality associated with preterm birth: gaps in knowledge of the impact of antenatal corticosteroids on preterm birth outcomes in low-middle income countries. Reproductive health. 2016; 13 (1):61. Epub 2016/05/24. https://doi.org/10.1186/s12978-016-0180-6 PMID: 27221397; PubMed Central PMCID: PMC4877818.

82. Bailey SM, Sarmandal P., Grant J.M. A comparison of three methods of assessing inter-observer variation applied to measurement of the symphysis-fundal height. British Journal of Obstetrics and Gynaecology. 1989; 96:1266–71. https://doi.org/10.1111/j.1471-0528.1989.tb03223.x PMID: 2611167