Chapter 3

Standard fundal height growth curve

Standard fundal height growth curve (SFHGC) is a curve of FH in centimeters throughout pregnancy derived from a normal population, a normal pregnancy involving a normal birth weight infant. Therefore, it can be used as a norm of FH in each population. The SFHGC is presented by graph of percentile line in each level, for example, 5th, 10th, 50th, 90th, and 95th percentile or line of mean and ±standard deviation. The y-axis is FH in centimeters and the x-axis is GA in weeks.

From 1972 to 1977, Westin[1] developed the SFHGC for the first time in Sweden by deriving and comparing the growth curves of FH, maternal weigh, and maternal girth of normal pregnancy with a mean birth weight ±1 standard deviation. He found that FH curve exhibited a smaller biological variation than others and highly correlated with fetal crown-rump length throughout pregnancy. In addition, the FH curve of LGA and SGA fetuses differed from those appropriate for gestational age (AGA) fetus and noticed that the FH growth curve above mean +2SD was able to detect large for date infants (BW above mean +1SD) at 65% and FH growth curve below mean -2SD was able to detect small for date infants (BW below mean -1SD) 75%. Therefore, Westin chose the FH curve to monitor fetal growth and detect accelerated and restriction growth of the fetus, when FH in centimeters within normal limit could imply normal, when deviating from normal (±2cm from mean) and may be at risk for abnormal. This curve was well known in terms of the gravidogram and was recommended for use in high risk groups such as IUGR, LGA, twin pregnancy and polyhydramnios both in developed and developing countries.

In 1978, Belizan et al.[2] constructed SFHGC during pregnancy with 10th, 50th, and 90th percentile lines from the normal values of FH in centimeters, called the Belizan chart, which was widely used in South Africa to detect IUGR when FH in centimeters was below the 10th percentile line. The sensitivity and specificity of the Belizan chart in detecting LBW infants (BW below 10th percentile) was 86% and 90%, respectively. The SFHGC of the Belizan chart was similar to Westin's gravidogram but its growth rate was slightly low in the near term period.

In 1982, Calvert et al.[3] derived the Caucasian FH growth curve, the Cardiff symphysis-fundus chart, which was recommended to use in Caucasian populations. Subsequently, it has been recommended to use in developing countries and low-income countries as a fetal growth screening method. However, it does not fit the local situation such as one study in India[4, 5] that found the SFHGC of a population in southern India was lower than the Caucasian population by around 2-3 cms throughout pregnancy.[4] Moreover, one study in Tanzania,[6] East Africa, showed that the scatter plot of 403 measurements among 83 women in combination with the Cardiff symphysis-fundus chart, 132 measurements (32.9%) were below the 10th percentile line, while only two measurements were above the 90th percentile line. However, after using FH to create a scatter plot on FH growth chart based on the local population it fit better than the Cardiff symphysis-fundus chart, with a clear shift to the right of the percentile lines. These studies demonstrated that each population should have its own FH growth curve, a demographically specific FH growth curve, to use in monitoring fetal growth and screening for abnormal intrauterine growth rather than a universally derived curve, as the SFHGC is influenced by race and ethnicity, socioeconomics, nutritional status, FH measurement technique and menstrual or ultrasound dating.

Therefore, several countries worldwide has developed their own standard FH growth curves based on routine clinical practices which then demonstrated differences in the FH, rate of change in centimeters during growth spurts and characteristics of slope and curve patterns (Table 3.1). SFHGC has its characteristics following the final model of linear regression or polynomial regression (quadratic, cubic, or quartic equation)[7] and was applied to the smooth line of the FH growth curve. The standard form linear equation is $y = ax + b$; the quadratic equation is $y = ax^2 + bx + c$; the cubic equation is $y = ax^3 + bx^2 + cx + d$ and the quartic equation is $y = ax^4 + bx^3 + cx^2 + dx + e$.

Nevertheless, a systematic review toward the ability of SFHGC to predict IUGR, SGA and LGA fetuses determined the sensitivity, specificity and positive predictive value significantly differed[8-15] which may have been caused from various screening tools, study methods, eligible criteria, definition of IUGR, SGA and LGA fetus, GA definition, measurement method, cutoff point of abnormal FH and statistical analysis. Therefore, many studies recommended how to improve ability of FH to detect abnormal intrauterine growth by the methods described below.[5, 8, 11, 16-20]

1. Create a SFHGC that suits a particular characteristic of each population and individuals whose normal norm used by a normal population is not applicable. SFHGC is a dynamic tool that can be changed following the normal population in a specific period especially in the globalization era when migrating populations are increasing. Cross-race marriages, nutritional changes and gestational age calculation are all more accurate than previously.

2. FH should be in centimeters on suitable standard FH growth curve in every antenatal care visit and frequently standardize FH measurement method.

3. Determine the proper guidelines to screen any abnormal condition in a specific population.

Standard FH growth curve in Thailand

In Thailand, healthcare providers have also use FH measurement as a primary screening tool to detect abnormal intrauterine growth in routine antenatal care (ANC) practice for ages as same as other countries around the world. However, recently, abnormal screening criteria are that FH in centimeters below or above GA in weeks more than 2-3 cms and did not use a FH growth chart as a tool to monitor and screen abnormal growth of the fetus.

Studies conducted on FH in centimeters of Thai women during pregnancy showed different results in each study (Table 3.1). In addition, SFHGC in a Thai population was first published in 1984 by Linasmita and Sugkraroek[21] who began to conduct research at

Ramathibodi Hospital and created a SFHGC from 1,295 measurements on the 415 normal singleton pregnancies who delivered infants with birth weights from 2,500 to 3,999 g with gestational age calculated from the first day of LMP. The FH growth chart showed 10th, 50th, and 90th percentile lines constructed using polynomial regression and applied in the antenatal care clinic in Ramathibodi Hospital.

In 2001, a new standard fundal height growth curve was created by Limpanyalert and Manotaya[17] based on ultrasound that confirmed LMP dating in King Chulalongkorn Memorial Hospital from 879 measurements on 199 normal singleton pregnancies involving infant BWs between the 10th and 90th percentiles. The FH obtained from the quadratic regression equation was FH (cm) = -7.7152 + 1.6365 GA (wk) - 0.0124 GA^2 (wk). The SFHGC was presented as a smoothed function of the 5th, 50th, and 95th percentiles exhibiting new SFHGC presenting different patterns from the one published in 1984.

RCOG has recommended to measure and plot FH in centimeters on customized growth charts, tools for assessing fetal growth and birth weight at every antenatal visit to detect fetal growth problems, especially SGA fetus and added the suggestions as Guidelines of RCOG since 2002 until the present.[22, 23] Several countries have developed their own customized growth charts for suitable screening tool in their own setting such as Australia, New Zealand, the United States, the Netherlands, Ireland, Spain, Sweden, Brazil and India.[20]

Deeluea et al.[24] aware of advantages and values of SFHGC utilize as a primary screening tool in Thailand, thus using the mentioned tool in the setting was established. However, FH growth curve since 1984[21] and 2001[17] had limitation of utilizing nowadays because 2 studies had derived base on their own settings which conducted in university hospitals located in the capital city leading to some limitations when using in community and local hospitals, where pregnant women have middle to poor economic status. Moreover, study in 1984[21] calculated GA from LMP which did not confirmed by US and study in 2001[17] calculated GA from US alone which different from routine practice in upper northern Thailand.

In 2012, Deeluea et al. [24] derived the local standard FH growth curve for Thai women in upper northern Thailand, based on routine clinical practices in four Ministry of Public Health hospitals, including two secondary care hospitals: Phayao Hospital and Lamphun Hospital, and two tertiary care hospitals: Lampang Hospital and Nakhon Ping Hospital. All four settings exhibited similar patterns of pregnant women in which the majority had middle to poor economic status and had similar guidelines for antenatal care practices. FH measurement was performed by nurses or physicians at every antenatal visit, which was measured in centimeters from the upper border of the symphysis pubis to the top of the uterine fundus, or reversed direction using a non-elastic measuring tape. SFHGC was derived using 7,523 measurements of 1,038 normal Thai singleton pregnancies that delivered term normal infants BW from 2,500 to 3,999 g for which gestational age was confirmed by ultrasound before 20 weeks. When gestational age by LMP and ultrasound were both related, then it was calculated using LMP.

When not, it was calculated using ultrasound. Pregnant women with current smoking, alcohol drinking, substance use, abnormal fetal presentation, and fetal anomaly were excluded from this study.

The result found that FH increased from 19.1±1.9 cm at 20 weeks to 35.4±2.4 cm at 40 weeks. The second degree polynomial equation was: FH (cm) = -19.7882 + 2.438157 GA (wk) - 0.0262178 GA^2 (wk) (R-squared=0.85). This equation was used to predict the 10th, 50th, and 90th percentiles of FH and was applied to smooth each percentile line. The new SFHGC "Jirawan FH growth curve" was presented as a smoothed function of the 10th, 50th, and 90th percentile lines between 20 and 40 weeks of gestation. It presented a quadratic pattern for which FH growth rate showed a maximum increase of 1.0 cm per week from 20 to 32 weeks, 0.7 cm per week from 33 to 36 weeks, and slightly increased 0.3 cm per week from 37 to 40 weeks (Figure 3.1). It differed from previous studies in the aspect of value of FH in centimeters, slope and curve pattern. These could be due to differences in race and ethnicity, nutritional status, measurement of fundal height, gestational age calculation, data collection and statistical analysis (Table 3.1).

The pattern of the Jirawan FH growth curve was similar to previous studies in Thailand,[17, 21] Tanzania,[6] and Nigeria[28] presenting the quadratic pattern, but differed from studies in Sweden[25, 26] and Mozambique[27] which exhibited the cubic pattern. The reasons can be the stature and pelvic cavity of Thai women that are smaller than Caucasian women,[32] causing an increase a FH early in pregnancy. In contrast, Caucasian women have larger stature and a wider pelvic cavity[33] which cause increasing in pattern of FH like an S-shaped, sigmoid curve or cubic pattern which the FH will increase very slowly in the beginning. However, in middle phase the FH will increase rapidly and then in the last phase the FH will increase slowly again.

The decreasing growth rate of FH around term might be because subjects in this study were nulliparous about 50.4%,[24] for which the presentation will engage approximately 2 to 4 weeks before delivery. However, from the 2001 study in Thailand,[17] the slope of FH increased constantly until 39 weeks of gestation. This might have been because most subjects were multiparous (61.3%) for which the presentation will engage during the labor stage. Black women with African ethnicity with an anthropoid pelvis who presented a similar FH growth curve pattern as Thai women, but did not decline around term due to the anthropoid pelvis, oval shaped inlet with long anteroposterior diameter and short transverse diameter,[34] causing a slowing down in the engagement of the fetal head in the pelvic inlet. An exception was observed in some African ethnics with gynecoid pelvis.[35]

Table 3.1 Fundal height in cm per week of gestation from various countries worldwide

Country	Reference	No. of women	No. of measurements	Data collection	GA by LMP or US	FH measured method	Subjects	Mean or centile of FH in cm	GA (wk) and FH (cm)					
									20	24	28	32	36	40
Sweden	Westin, 1977[1]	100	Unknown	Longitudinal	LMP	SP to Top	Normal	Mean	18.0	22.0	26.0	29.5	33.0	35.5
Sweden	Hakansson et al., 1995[25]	403	4,189	Longitudinal	US	SP to Top Westin	Normal	Mean	19.0	23.0	27.0	30.5	33.5	35.5
Sweden	Steingrimsdottir et al., 1995[26]	1,650	1,650	X-sectional	US	SP to Top Westin	Normal	Mean	19.0	23.1	27.1	30.1	33.6	35.8
Scandinavia	Pay et al., 2013[16]	42,018	282,713	Retrospective Longitudinal	US	SP to Top Westin	All singleton +complication	50th centiles	-	23.2	26.7	30.4	33.7	36.3
UK	Calvert et al., 1982[3]	313	1,775	Prospective Longitudinal	LMP	Top to SP	Normal	50th centiles	18.8	22.9	26.8	30.2	33.7	36.2
Argentina	Belizán et al., 1978[2]	298	1,508	Longitudinal	LMP	SP to Top	Normal	50th centiles	18.5	22.5	26.5	30.5	33.5	34.5
Tanzania	Walraven et al., 1995[6]	83	403	Prospective Longitudinal	LMP	SP to Top	Normal	Mean	16.2	20.3	23.6	27.8	31.2	33.6
Mozambique	Challis et al., 2002[27]	817	6,544	Prospective Longitudinal	US	SP to Top Westin	All subgroup	50th centiles	19.0	23.0	26.8	30.0	33.0	35.0
Nigeria	Mador et al., 2010[28]	405	405	Prospective X-sectional	US	SP to Top	Normal	50th centiles	19.1	24.4	28.3	32.0	35.8	39.3
Hong Kong	Ngan et al., 1988[29]	Unknown	1,051	Prospective Longitudinal	LMP	SP to Top	Normal	Mean	17.9	22.0	25.9	29.5	32.8	36.1
India	Mathai et al., 1987[4]	250	584	Prospective Longitudinal	LMP	SP to Top	Normal	Mean	18.0	21.5	24.5	27.5	31.5	33.5
India	Rai et al., 1995[30]	100	523	Prospective Longitudinal	LMP/US	SP to Top	Normal	Mean	18.9	22.8	26.9	31.0	34.4	37.3
Thailand	Linasmita et al., 1984[21]	415	1,295	Prospective Longitudinal	LMP	SP to Top (Figure 2.4)	Normal	50th centiles	17.7	23.1	26.4	30.4	32.9	34.6
Thailand	Limpanyalert et al., 2001[17]	199	879	Prospective Longitudinal	LMP/US	Top to SP	Normal	50th centiles	20.1	24.4	28.4	32.0	35.1	37.9
Thailand	Deeluea et al., 2013[24]	1,038	7,523	Retrospective Time-series	LMP and US	Top to SP SP to Top	Normal	50th centiles	18.7	23.7	28.0	31.4	34.0	35.8
International 8 countries	Papageorghiou et al, 2016[31]	4,239	20,566	Prospective Longitudinal	LMP/US	Top to SP SP to Top	Normal	50th centiles	20.0	24.0	27.5	31.5	35.0	38.0

Abbreviations: GA, gestational age; LMP, last menstrual period; US, ultrasound; FH, fundal height; SP, symphysis pubis; Top, top of uterine fundus; GA by LMP/US, dated calculated by LMP which confirmed by US; GA by LMP and US, dated confirmed by US calculated by LMP or US; Westin: The method of FH is measured from the upper border of the symphysis pubis along the longitudinal axis of the uterus to the topmost of the uterus, whether within or outside the midline.

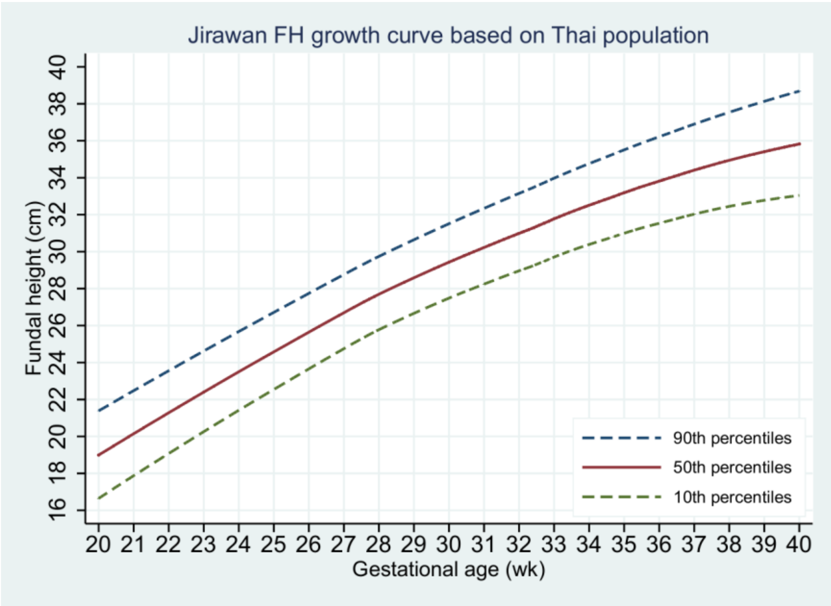

Figure 3.1 Jirawan FH growth curve derived from 7,523 measurements of 1,038 normal Thai singleton pregnancies with dates confirmed by ultrasound before 20 weeks of gestation with 10th, 50th, and 90th percentile lines, fitted by a quadratic regression.[24]

When comparing SFHGC among the Thai population, the Jirawan FH growth curve was 1.0 cm above the study in 1984,[21] but 0.5 to 1.0 cm below the study in 2001 (Figure 3.2). These could be due to the factors described below.

1. Population characteristics: mean BW infant in Thailand tended to increase from 2,933 g in 1982[36] to 3,117 g in 2011[37]; thus, the SFHGC in this study increased following the mean BW of infants. In 2001[17] the SFHGC was higher might be because most subjects were multiparous.

2. Gestational age calculation: it was worth noticing that gestational age in three studies used different criteria: LMP,[21] ultrasound,[17] and LMP or ultrasound.[24] GA calculated based on LMP tends to be overestimated by ultrasound.[38, 39] However, in this study GA based on LMP and ultrasound was very similar. These could have been because most subjects in this study presented normal BMI (21.6±3.8 kg/m^2).[24] Therefore, the errors from ultrasound reading were less than those of women who had overweight or obese.[40]

3. Data analysis: The regression technique was used to create new SFHGCs for Thai women by correlating FH in centimeters and GA during pregnancy for the same subject. A multilevel model for continuous data using longitudinal data proved to be more appropriate than cross-sectional data used to create the SFHGC in 2001.[41]

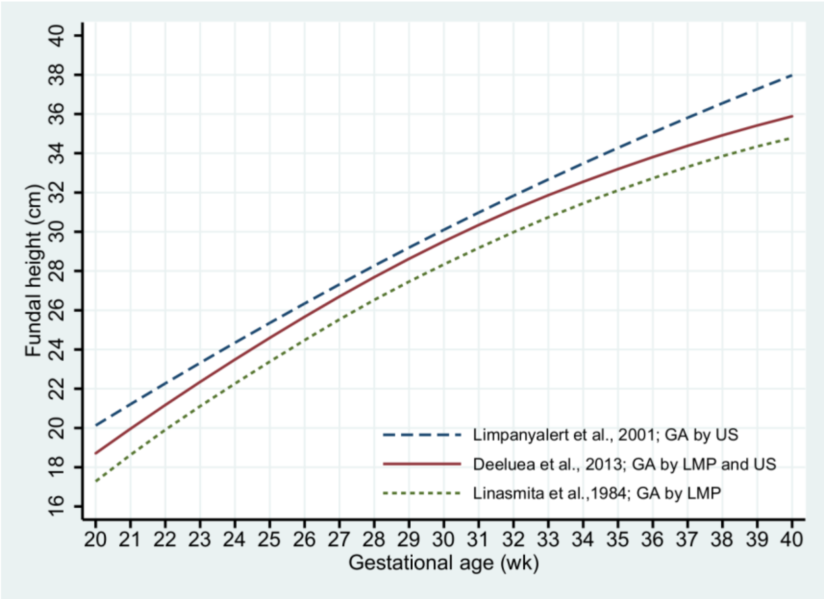

Figure 3.2 Compared 50th percentile lines of standard FH growth curve in a Thai population[24]

The abnormal screening criteria used in this study comprised the 10th to 90th percentile line to focus on screening rather than diagnosis. Further investigation is recommended when FH in centimeters is below the 10th, or above the 90th percentile lie, the pattern of FH slows down, becomes static, decreases or increases dramatically. The effectiveness of screening using the Jirawan FH growth curve will be continued to study for further information.

In conclusion as mentioned above, each population should have its own individual SFHGC to use in monitoring and screening abnormal intrauterine growth. Even in the same country, different contexts, i.e., ethnicity, socioeconomics, routine ANC practices, can also lead to differences in SFHGC. The Jirawan FH growth curve can be used as a norm of FH among Thai women in northern Thailand instead of using the FH in centimeters equals to GA in weeks ±2.

References

1. Westin B. Gravidogram and fetal growth: comparison with biochemical supervision. Acta Obstet Gynecol Scand. 1977;56(4):273-82.

2. 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.

3. Calvert JP, Crean EE, Newcombe RG, Pearson JF. Antenatal screening by measurement of symphysis-fundus height. Br Med J. 1982;285(6345):846-9.

4. Mathai M, Jairaj P, Muthurathnam S. Screening for light-for-gestational age infants: a comparison of three simple measurements. BJOG. 1987;94(3):217-21.

5. Grover V, Usha R, Kalra S, Sachdeva S. Altered fetal growth: antenatal diagnosis by symphysis-fundal height in India and comparison with western charts. Int J Gynaecol Obstet. 1991;35(3):231-4.

6. Walraven GE, Mkanje RJ, van Dongen PW, van Roosmalen J, Dolmans WM. The development of a local symphysis-fundal height chart in a rural area of Tanzania. Eur J Obstet Gynecol Reprod Biol. 1995;60(2): 149-52.

7. Grimm KJ, Ram N, Hamagami F. Nonlinear growth curves in developmental research. Child Dev. 2011; 82(5):1357-71.

8. Roex A, Nikpoor P, van Eerd E, Hodyl N, Dekker G. Serial plotting on customised fundal height charts results in doubling of the antenatal detection of small for gestational age fetuses in nulliparous women. Aust N Z J Obstet Gynaecol. 2012;52(1):78-82.

9. Goto E. Prediction of low birthweight and small for gestational age from symphysis-fundal height mainly in developing countries: a meta-analysis. J Epidemiol Community Health. 2013;67(12):999.

10. Kayem G, Grange G, Breart G, Goffinet F. Comparison of fundal height measurement and sonographically measured fetal abdominal circumference in the prediction of high and low birth weight at term. Ultrasound Obstet Gynecol. 2009;34(5):566-71.

11. Morse K, Williams A, Gardosi J. Fetal growth screening by fundal height measurement. Best Pract Res Clin Obstet Gynaecol. 2009;23(6):809-18.

12. Neilson JP. Symphysis-fundal height measurement in pregnancy. Cochrane Database Syst Rev. 2009(1): CD000944.

13. Freire DM, Cecatti JG, Paiva CS. Symphysis-fundal height curve in the diagnosis of fetal growth deviations. Rev Saude Publica. 2010;44(6):1031-8.

14. Sparks TN, Cheng YW, McLaughlin B, Esakoff TF, Caughey AB. Fundal height: a useful screening tool for fetal growth? J Matern Fetal Neonatal Med. 2011;24(5):708-12.

15. Robert Peter J, Ho JJ, Valliapan J, Sivasangari S. Symphysial fundal height (SFH) measurement in pregnancy for detecting abnormal fetal growth. Cochrane Database Syst Rev. 2012(7):CD008136.

16. Pay AS, Froen JF, Staff AC, Jacobsson B, Gjessing HK. A new population-based reference curve for symphysis-fundus height. Acta Obstet Gynecol Scand. 2013;92(8):925-33.

17. Limpanyalert P, Manotaya S. Standard curve of symphysial-fundal height measurement and pregnancy characteristics in pregnant women at King Chulalongkorn Memorial hospital. Thai J Obstet Gynaecol. 2001;13 (4):197-206.

18. Wright J, Morse K, Kady S, Francis A. Audit of fundal height measurements plotted on customised growth charts. MIDIRS. 2006;16(3):341-5.

19. Figueras F, Gardosi J. Intrauterine growth restriction: new concepts in antenatal surveillance, diagnosis, and management. Am J Obstet Gynecol. 2011;204(4):288-300.

20. Gardosi J. Customised assessment of fetal growth potential: implications for perinatal care. Arch Dis Child Fetal Neonatal Ed. 2012;97(5):F314-7.

21. Linasmita V, Sugkraroek P. Normal uterine growth curve by measurement of symphysial-fundal height in pregnant women seen at Ramathibodi Hospital. J Med Assoc Thai. 1984;67 Suppl 2:22-6.

22. Royal College of Obstetricians and Gynaecologists. The investigation and management of the small-for-gestational-age fetus (Guideline no. 31) London: RCOG; 2002.

23. Royal College of Obstetricians and Gynaecologists. The investigation and management of the small-for-gestational-age fetus (Green-top Guideline No. 31). 2nd ed. London: RCOG; 2013.

24. Deeluea J, Sirichotiyakul S, Weerakiet S, Buntha R, Tawichasri C, Patumanond J. Fundal height growth curve for Thai women. ISRN Obstet Gynecol. 2013;2013:463598.

25. Hakansson A, Aberg A, Nyberg P, Schersten B. A new symphysis-fundus height growth chart based on a well defined female population with ultrasound-dated singleton pregnancies. Acta Obstet Gynecol Scand. 1995;74(9):682-6.

26. Steingrimsdottir T, Cnattingius S, Lindmark G. Symphysis-fundus height: construction of a new Swedish reference curve, based on ultrasonically dated pregnancies. Acta Obstet Gynecol Scand. 1995;74(5): 346-51.

27. 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. Trop Med Int Health. 2002;7(8):678-84.

28. Mador ES, Pam SD, Pam IC, Mutihir JT, Adoga GI, Ogunranti JO. Symphysio-fundal height nomogram in ultrasound dated pregnancies. AJMS. 2010;1(2):64-7.

29. Ngan HYS, Woo JSK, Fung KP, Au KKL. A symphysis-fundal height nomogram for Hong Kong Chinese. Hong Kong Med J. 1988;40(1):55-7.

30. Rai L, Kurien L, Kumar P. Symphysis fundal height curve--a simple method for foetal growth assessment. J Postgrad Med. 1995;41(4):93-4.

31. Papageorghiou AT, Ohuma EO, Gravett MG, Hirst J, da Silveira MF, Lambert A, Carvalho M, Jaffer YA, Altman DG, Noble JA, Bertino E, Purwar M, Pang R, Cheikh Ismail L, Victora C, Bhutta ZA, Kennedy SH, Villar J. 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. 2016;355:i5662.

32. Nystrom MJ, Caughey AB, Lyell DJ, Druzin ML, El-Sayed YY. Perinatal outcomes among Asian-white interracial couples. Am J Obstet Gynecol. 2008;199(4):385.e1-5.

33. Handa VL, Lockhart ME, Fielding JR, Bradley CS, Brubaker L, Cundiff GW, Ye W, Richter HE. Racial differences in pelvic anatomy by magnetic resonance imaging. Obstet Gynecol. 2008;111(4):914-20.

34. Walrath D. Rethinking pelvic typologies and the human birth mechanism. Curr Anthropol. 2003;44(1):5-31.

35. Bukar M, Mustapha Z, Ahidjo A, Bako G. Pelvic types as seen in a tropical setting. Niger J Med. 2010; 19(1):42-5.

36. Chaturachinda K, Hiranraks A, Auamkul N, Kanchanasinith K, Amornvichet P, P OP. Low birthweight in Thailand: 1982. J Med Assoc Thai. 1993;76 Suppl 1:36-9.

37. Annual report of maternal-fetal medicine 2011 [Internet]: Department of Obstetrics and Gynecology, Faculty of Medicine, Chiang Mai University; 2011. Available from: http://www.med.cmu.ac.th/dept/ obgyn/2011/images/stories/MFM/Statistics/MFM11.pdf.

38. Savitz DA, Terry JW, Jr., Dole N, Thorp JM, Jr., Siega-Riz AM, Herring AH. Comparison of pregnancy dating by last menstrual period, ultrasound scanning, and their combination. Am J Obstet Gynecol. 2002;187(6):1660-6.

39. Barr WB, Pecci CC. Last menstrual period versus ultrasound for pregnancy dating. Int J Gynaecol Obstet. 2004;87(1):38-9.

40. Simic M, Wahlin IA, Marsal K, Kallen K. Maternal obesity is a potential source of error in mid-trimester ultrasound estimation of gestational age. Ultrasound Obstet Gynecol. 2010;35(1):48-53.

41. Rabe-Hesketh S, Skrondal A. Multilevel and longitudinal modeling using Stata. 2nd ed. Texas, USA: Stata Press; 2008.