Review Article

Fetal Weight Estimation: Importance, Challenges and Emerging Trends

Syed Nudrat Nawaid Shah[1] , Nuzhat Hassan[2]

Abstract

Accurate fetal weight estimation is important in preventing and managing fetal and maternal complications. Many fetal weight formulae have been derived, but none seems to be accurate enough to be applied globally for all ranges of fetal weight. Major factors causing errors in fetal weight estimation include inappropriately derived equations not considering ethnic differences among populations, fetal gender difference and different ranges of fetal weight. Use of fetal thigh volume and arm volume for fetal weight estimation by 3D ultrasound may increase the precision of fetal weight formulae. However, the superiority of 3D ultrasound in fetal weight estimation over 2D ultrasound is debatable as greater expertise is required, time consumed is more and there is no substantial increase in accuracy. It is suggested that fetal gender specific, fetal weight range specific and community based formula should be derived and used for better accuracy. Further studies are recommended. Articles published between October 1993 to October 2015 were selected from PubMed and Google Scholar, for this review article.

Keywords: Fetal weight estimation, sonography, femur, biparietal diameter, gender.

(ASH & KMDC 20(2):148;2015).

Fetal weight and its importance

Fetal weight estimation is an integral part of obstetrical examination and management planning. It is important to calculate fetal weight with precision as both increased and decreased fetal weight can result in complications during labor and puerperium[1-3]. Complications like preterm delivery[4-6] or intrauterine growth restriction (IUGR) are known to be associated with low fetal weight[7,8]. Fetal bone injuries, shoulder dystocia and brachial plexus injuries are reported with large fetal weight[9,10]. Similarly, maternal complications like pelvic floor and birth canal injuries are common in cases of large fetal weight[11]. Therefore, accurate fetal weight estimation can predict and prevent such complications and could greatly help in selecting appropriate management plan[12].

[1-2] Department of Anatomy,
Ziauddin University, Karachi, Pakistan.

Correspondence: Dr Syed Nudrat Nawaid Shah,
Department of Anatomy,
Ziauddin University,
Karachi, Pakistan.
E-mail: syednudratshah@gmail.com

Fetal weight evaluation

The most common method to measure fetal weight is by the help of 2D ultrasound. In this, fetal weight is calculated by using different formulae derived at different points in time using different sets of population[13]. There are more than 17 sonographic formulae reported in literature which are mostly based on parameters like femur length, abdominal circumference, head circumference and biparietal diameter[14]. These formulae use different combinations of the these parameters. Some are based on a single parameter like Campbell's formula, some are based on two parameters like Shepard's formula

and some are based on three or more parameters like Aoki's formula and Hadlock's formula. Which formula is better than the other has been scrutinized by many researchers reporting conflicting results[15]. Some studies suggest that increasing the number of parameters can improve the accuracy of the formula while few suggest that it does not make any substantial difference on the accuracy of the equation[16]. Formulae including abdominal parameters like abdominal circumference are reported to have better accuracy in measuring fetal weight. It may be because, as reported by researchers, they indirectly incorporate fetal liver growth and hepatic glycogen stores reflecting fetal nutritional status. Liver being the largest organ of abdomen greatly influences both fetal abdominal parameters and fetal weight[17].

Among these formulae, Hadlock, Campbell, Shepard and Aoki fetal weight formulae are widely used and tested by researchers[18]. Royal College of Obstetrics and Gynaecology reported Shepard and Aoki formulae to have better accuracy in predicting fetal weight within the normal range of fetal weight but their use outside the normal range is suggested to be inappropriate[19]. Better accuracy obtained from Aoki,s formula might be due to use of three fetal parameters that are biparietal diameter, fetal abdominal area and femur length. However, same level of accuracy is reported with Shepard formula which uses only two fetal parameters which are biparietal diameter and abdominal circumference[20]. Campbell formula is easier to use as it requires only one fetal parameter to be measured which is abdominal circumference, is reported to be as good as any other formula for average weighed infants[21]. It is also reported to be a better formulae in cases of fetal macrosomia[14]. Hadlocks formulae which uses four fetal parameters including head circumference, biparietal diameter, femur length and abdominal circumference is reported by researchers to be as accurate as other fetal weight formulae[22]. Better performance of Hadlock formulae is also reported for all weight ranges[23]. However, Royal College of Obstetrics and Gynecology guideline 2013 recommend Hadlocks formula for low weight fetuses[19] In Pakistan, the choice of using a particular fetal weight formulae depends on the individual obstetrician or radiologist. Although Hadlocks formulae is widely used in the country but Hadlock[1] and Hadlock[2] formulae were reported to be inappropriate for Pakistani population[24]. For Pakistani population, a new fetal weight estimation formulae was suggested which was claimed to have more accuracy and reliability by the authors[25]. Further studies are needed to evaluate it.

Majority of traditionally used formulae are neither population specific nor gender specific, and are used for all ranges of fetal weight[26]. No single formula is accepted as a standard formula which could be applied globally with accuracy[27,28]. The inaccuracies among these formulae vary greatly[29]. Within the normal range of fetal weight the mean error is reported between 7 to 10%[30], but the error increases as fetal weight either increases or decreases beyond the normal fetal weight range[31,32]. Most researchers suggest that fetal weight is under reported in cases of low birth weight and over reported in cases of high birth weight[33].

Factors causing errors in fetal weight estimation

Few reasons are suggested by different studies as the cause of inaccuracies in fetal weight estimation. Foremost among them is the use of inappropriate equations[34] because different equations were derived using different set of population giving best result only for that population[35]. Race and ethnicity are reported to affect the accuracy of fetal weight formulae considerably. Population specific equations are recommended for better accuracy[36,37].

Fetal gender is the other factor which affects the accuracy of fetal weight estimation. Most of the fetal weight formulae were derived not considering the effects of fetal gender on fetal weight[26]. Researchers have reported that male and female fetuses show statistically significant differences in head circumference, biparietal diameter, abdominal circumference and femur length[38]. Some researchers have also reported different growth patterns for

the two genders[39]. Use of different formula coefficients for male and female fetuses are also recommended for better accuracy[40]. Studies have also reported more inaccuracy in fetal weight estimation in female fetuses than in males suggesting the use of sex specific models for better accuracy of fetal weight estimation[41]. In recent years, sex specific fetal weight estimation formulae have been reported to have better accuracy[42].

Breech presentation of the fetus has been reported to be a cause of inaccurate fetal weight estimation in different studies[43], but some researchers also claim that fetal weight estimation with breech presentation is as accurate as with vertex presentation[44]. Twin pregnancy and inexperienced operator are other factors reported to decrease the accuracy of sonographic fetal weight estimation[45].

New approaches in 2D sonographic fetal weight estimation

In order to improve the accuracy of fetal weight estimation, recently new approaches and parameters have been suggested[46]. Some researchers have recommended that fetal mid-thigh soft tissue thickness is a simple, easy and useful parameter for assessing fetal weight[47]. It correlates well with estimated fetal weight and birth weight, and can be a valuable parameter for assessing fetal weight[48]. Inclusion of fetal mid-thigh soft tissue thickness with routinely used parameters in fetal weight formulae can improve their accuracy[49]. In 2D sonography, inclusion of soft tissue in fetal weight estimation can also be achieved by measuring fractional limb volume[50]. Incorporating fractional limb volume in conventional fetal weight formulae have yielded better precision[51]. A study conducted in Pakistan in 2008 reported that Isobe's formula ,which is based on femur length and cross sectional area of thigh, is more convenient and as accurate as other established fetal weight formulae[52].

Many researchers have shown that fetal weight formulae are not precise over the whole range of weight. Most fetal weight formulae perform better within a specific range of fetal weight[53]. In order to improve the precision of fetal weight formulae, separate fetal weight formula were suggested for both low fetal weight[54] as well as high fetal weight[55] which are reported to have better accuracy[56].

Fetal weight estimation using fetal thigh volume, fetal arm volume by 3D ultrasound. A new approach

Recently 3D sonography has emerged as a new tool for estimating fetal weight. New fetal weight formulae are being developed and evaluated for accuracy[57]. Parameters like fetal thigh volume, fetal arm volume and fetal liver volume are reported to have significant correlations with birth weight[58]. Some studies suggest that incorporation of fetal thigh volume and fetal arm volume in fetal weight formulae may improve the accuracy of fetal weight estimation while same level of accuracy even after including fetal thigh volume and fetal arm volume in fetal weight formulae have also been reported in a few studies[59,60].

3D ultrasound versus 2D ultrasound for fetal weight estimation

Contradictions exist among studies in reporting the accuracy of fetal weight estimation by 3D ultrasound over 2D ultrasound. Some studies suggest 3D ultrasound to be better in estimating fetal weight[61] while some suggest 2D ultrasound to be equally effective[62]. However, extra time and expertise is required for estimating fetal weight with 3D ultrasound which could limit its use[63].

Standardized fetal growth parameters chart and fetal weight estimation

Large number of locally derived fetal growth charts and large variation in the reference points like 3rd percentile, 5th percentile or 10th percentile has made it difficult to establish whether the growth of the fetus is abnormal[64]. A globally acceptable standardized fetal growth chart and fetal weight estimation is needed[65]. To solve this problem University of Oxford, funded by Bill and Melinda Gates Foundation, started a multicenteric project named

"Intergrowth - 21st Project" in 2009 with the aim to construct an internationally acceptable standard for fetal growth parameters and fetal weight estimation[66]. From conception to infancy, anthropometric measures were developed[67]. New internationally standardized fetal growth charts of parameters like biparietal diameter, head circumference, femur length, abdominal circumference were developed during this project which were published in 2014. In this project, from 14th week to 42nd week of gestation, sonographic evalution was done after every 5th week. Abdominal circumference, occipetofrontal diameter, biparietal diameter, femur length and head circumference were measured. 3rd, 5th 10th, 50th, 90th, 95th and 97th centile curves according to gestational age were developed which showed small differences between smoothed centiles and observed means[68]. New sex specific 3rd, 10th, 50th, 90th, and 97th centile curves for head circumference, weight and length of neonates according to gestational age at birth were developed[69]. A new model for CRL measurement was developed for correct estimation of age of gestation[70]. These international fetal growth standards are recommended for clinical application across populations. More results are awaited from this project.

Conclusion

Large number of fetal weight formulae applied in different parts of the world suggests that no standard and accurate fetal weight formula is available. Improvements can be made in the accuracy of fetal weight formula by considering the effect of gender and ethnicity while designing these formulae. Separate fetal weight formula for different fetal weight range could increase the accuracy of the formulae. Fetal weight estimation by 3D ultrasound using fetal thigh and arm volume has opened a new window of opportunity. Further research is needed to check if fetal weight estimation by 3D ultrasound is superior to 2D ultrasound. New international fetal growth standards are developed during "Intergrowth - 21st Project" which are recommended for clinical use across populations.

Conflict of interest

Authors have no conflict of interests and no grant/ funding from any organization.

References

1. Sung IK, Vohr B, Oh W. Growth and neurodevelopmental outcome of very low birth weight infants with intrauterine growth retardation: comparison with control subjects matched by birth weight and gestational age. J Pediatr 1993;123:618-24.
2. Bardin C, Zelkowitz P, Papageorgiou A. Outcome of small-for gestational age and appropriate-for-gestational age infants born before 27 weeks of gestation. Pediatrics 1997;100:E4.
3. Roth S, Chang TC, Robson S, Spencer JA, Wyatt JS, Stewart AL. The neurodevelopmental outcome of term infants with different intrauterine growth characteristics. Early Hum Dev 1999;55:39-50
4. Lysikiewicz A, Bracero LA, Tejani N. Sonographically estimated fetal weight percentile as a predictor of preterm delivery. J Matern Fetal Med 2001;10:44-7.
5. Lackman F, Capewell V, Richardson B, daSilva O, Gagnon R. The risks of spontaneous preterm delivery and perinatal mortality in relation to size at birth according to fetal versus neonatal growth standards. Am J Obstet Gynecol 2001;184:946-53.
6. Hediger ML, Scholl TO, Schall JI, Miller LW, Fischer RL. Fetal growth and the etiology of preterm delivery. Obstet Gynecol 1995;85:175-82.
7. Pilliod RA, Cheng YW, Snowden JM, Doss AE, Caughey AB. The risk of intrauterine fetal death in the small-for-gestational-age fetus. Am J Obstet Gynecol 2012;207:318.
8. Lackman F, Capewell V, Richardson B, daSilva O, Gagnon R. The risks of spontaneous preterm delivery and perinatal mortality in relation to size at birth according to fetal versus neonatal growth standards. Am J Obstet Gynecol 2001;184:946-53.
9. Overland EA, Vatten LJ, Eskild A. Pregnancy week at delivery and the risk of shoulder dystocia: a population study of 2,014,956 deliveries. BJOG 2014;121:34-41.
10. Jevitt CM. Shoulder dystocia: etiology, common risk factors, and management. J Midwifery Womens Health 2005;50:485-97.
11. Hehir MP, O'Connor HD, Higgins S, Robson MS, McAuliffe FM, Boylan PC, Malone FD, Mahony R. Obstetric anal sphincter injury, risk factors and method of delivery - an 8-year analysis across

two tertiary referral centers. J Matern Fetal Neonatal Med 2013;26:1514-6.

12. Perlow JH, Wigton T, Hart J, Strassner HT, Nageotte MP, Birth trauma. A five year review of incidence and associated perinatal factors. J Reprod Med 1996;41:754?60.
13. Bajracharya J, Shrestha NS, Karki C. Accuracy of prediction of birth weight by fetal ultrasound birth weight by fetal ultrasound. Kathmandu Univ Med J 2012;10:74-6.
14. Rosati P, Arduini M, Giri C, Guariglia L. Ultrasonographic weight estimation in large for gestational age fetuses: a comparison of 17 sonographic formulas and four models algorithms. J Matern Fetal Neonatal Med 2010;23:675-80.
15. Melamed N, Yogev Y, Meizner I, Mashiach R, Bardin R, Ben-Haroush A. Sonographic fetal weight estimation: which model should be used? J Ultrasound Med 2009;28:617-29.
16. Barel O, Vaknin Z, Tovbin J, Herman A, Maymon R. Assessment of the accuracy of multiple sonographic fetal weight estimation formulas: a 10-year experience from a single center. J Ultrasound Med 2013;32:815-823.
17. Gardosi J. Ultrasound biometry and fetal growth restriction. Fetal and Maternal Medicine Review 2002;13:249-59. Available from: https://www.perinatal.org.uk/gap/Resources/Ultrasound_Biometry_and_Fetal_Growth_Restriction.pdf
18. Pinette MG, Pan Y, Pinette SG. Estimation of Fetal Weight: Mean Value from Multiple Formulas. J Ultrasound Med 1999;18:813-7.
19. Royal College of Obstetrician and Gynaecologist. Small-for-Gestational-Age Fetus, Investigation and Management (Green-top Guideline No. 31). RCOG; 2013. Available at: www.gestation.net/rcog%20small_gest_age_fetus_no31.pdf. Accessed on August 25, 2015.
20. Chien PF, Owen P, Khan KS. Validity of ultrasound estimation of fetal weight. Obstet Gynecol 2000;95:856-60.
21. Stratton J, Ní Scanaill S, Stuart B, Turner MJ. Which formula should be used in Ireland to estimate fetal weight? Ir Med J 1996;89:30-1.
22. Kumara DM, Perera H. Evaluation of six commonly used formulae for sonographic estimation of fetal weight in a Sri Lankan population. Sri Lanka Journal of Obstetrics and Gynaecology 2009;31:20-33. Available from: http://sljog.sljol.info/articles/abstract/10.4038/sljog.v31i1.1735/
23. Kurmanavicius J, Burkhardt T, Wisser J, Huch R. Ultrasonographic fetal weight estimation: accuracy of formulas and accuracy of examiners by birth weight from 500 to 5000 g. J Perinat Med 2004;32:155-61.
24. Akhtar W, Ali A, Aslam M, Saeed F, Salman, Ahmad N. Birth weight estimation--a sonographic model for Pakistani population. J Pak Med Assoc 2010;60:517-20.
25. Munim S, Figueras F, Shah SM, Khan F, Gardosi J. Ultrasound estimation of fetal weight: a formula for a Pakistani population. J Obstet Gynaecol Res 2010;36:479-83.
26. Schild RL, Sachs C, Fimmers R, Gembruch U, Hansmann M: Sex-specific fetal weight prediction by ultrasound. Ultrasound Obstet Gynecol 2004;23:30-5.
27. Dudley NJ. A systematic review of the ultrasound estimation of fetal weight. Ultrasound Obstet Gynecol 2005;25:80-9.
28. Burd I, Srinivas S, Paré E, Dharan V, Wang E. Is sonographic assessment of fetal weight influenced by formula selection? J Ultrasound Med 2009;28:1019-24.
29. Bajracharya J, Shrestha NS, Karki C. Accuracy of prediction of birth weight by fetal ultrasound birth weight by fetal ultrasound. Kathmandu Univ Med J (KUMJ) 2012;10:74-6.
30. Colman A, Maharaj D, Hutton J, Tuohy J. Reliability of ultrasound estimation of fetal weight in term singleton pregnancies. NZ Med J 2006;119:U2146.
31. Scioscia M, Vimercati A, Ceci O, Vicino M, Selvaggi LE. Estimation of birth weight by two-dimensional ultrasonography: a critical appraisal of its accuracy. Obstet Gynecol 2008;111:57-65.
32. Abele H, Hoopmann M, Wagner N, Hahn M, Wallwiener D, Kagan KO. Accuracy of sonographic fetal weight estimation of fetuses with a birth weight of 1500 g or less. Eur J Obstet Gynecol Reprod Biol 2010;153:131-7.
33. Kumarasiri S, Wanigasekara R, Wahalawatta L, Jayasinghe L, Padeniya T, Dias T. Accuracy of ultrasound estimated fetal weight formulae to predict actual birth weight after 34 weeks: prospective validation study. Ceylon Med J 2013;58:116-21.
34. Anderson NG, Jolley IJ, Wells JE. Sonographic estimation of fetal weight: comparison of bias, precision and consistency using 12 different formulae. Ultrasound Obstet Gynecol 2007;30:173-9.
35. Souka AP, Papastefanou I, Michalitsi V, Pilalis A, Kassanos D. Specific formulas improve the estimation of fetal weight by ultrasound scan. J Matern Fetal Neonatal Med 2014;27:737-42.

36. Barel O, Vaknin Z, Tovbin J, Herman A, MaymonR. Assessment of the accuracy of multiple sonographic fetal weight estimation formulas: a 10-year experience from a single center. J Ultrasound Med 2013;32:815-23.

37. Benavides-Serralde A, Hernandez-Andrade E, Fernandez-Lara A, Figueras F. Accuracy of different equations for estimating fetal weight. Gynecol Obstet Invest 2011;7:264-8.

38. L'ubuský M, Mícková I, Procházka M, Dzvincuk P, Malá K. Discrepancy of ultrasound biometric parameters of the head (HC--head circumference, BPD--biparietal diameter) and femur length in relation to sex of the fetus and duration of pregnancy]. Ceska Gynekol 2006;71:169-72.

39. Melamed N, Meizner I, Mashiach R, Wiznitzer A, Glezerman M, Yogev Y. Fetal sex and intrauterine growth patterns. J Ultrasound Med 2013;32:35-43.

40. Melamed N, Yogev Y, Ben-Haroush A, Meizner I, Mashiach R, Glezerman M. Does use of a sex-specific model improve the accuracy of sonographic weight estimation? Ultrasound Obstet Gynecol 2012;39:549-57.

41. Melamed N, Ben-Haroush A, Meizner I, Mashiach R, Glezerman M, Yogev Y. Accuracy of sonographic weight estimation as a function of fetal sex. Ultrasound Obstet Gynecol 2011;38:67-73.

42. Barel O, Maymon R, Barak U, Smorgick N, Tovbin J, Vaknin Z. A search for the most accurate formula for sonographic weight estimation by fetal sex - a retrospective cohort study. Prenat Diagn 2014;34:1337-44.

43. Melamed N, Ben-Haroush A, Meizner I, Mashiach R, Yogev Y, Pardo J. Accuracy of sonographic fetal weight estimation: a matter of presentation. Ultrasound Obstet Gynecol 2011;38:418-24.

44. Dammer U, Goecke TW, Voigt F, Schmid M, Mayr A. Sonographic weight estimation in fetuses with breech presentation. Arch Gynecol Obstet 2013;287:851-8.

45. Jetal S. Fetal weight estimation by ultrasound: comparison of 11 different formulae and examiners with differing skill levels. Ultraschall Med 2008;29:159-64.

46. Kehl S, Schmidt U, Spaich S, Schild RL, Sütterlin M. What are the limits of accuracy in fetal weight estimation with conventional biometry in two-dimensional ultrasound? A novel postpartum study. Ultrasound Obstet Gynecol 2012;39:543-8.

47. Abuelghar W, Khairy A, El Bishry G, Ellaithy M, Abd-Elhamid T. Fetal mid-thigh soft-tissue thickness: a novel method for fetal weight estimation. Arch Gynecol Obstet 2014;290:1101-8.

48. Scioscia M, Scioscia F, Vimercati A, Caradonna F. Estimation of fetal weight by measurement of fetal thigh soft-tissue thickness in the late third trimester. Ultrasound Obstet Gynecol 2008;31:314-20.

49. Larciprete G, Di Pierro G, Barbati G, Deaibess T, Jarvis S. Could birthweight prediction models be improved by adding fetal subcutaneous tissue thickness? J Obstet Gynaecol Res 2008;34:18-26.

50. Lee W, Deter R, Sangi-Haghpeykar H, Yeo L, Romero R. Prospective validation of fetal weight estimation using fractional limb volume. Ultrasound Obstet Gynecol 2013;41:198-203.

51. Lee W, Balasubramaniam M, Deter RL, Yeo L. New fetal weight estimation models using fractional limb volume. Ultrasound Obstet Gynecol 2009;34:556-65.

52. Saqib R, Siddiqui TS, Siddiqui TS, Fatima S. Estimation of foetal weight in third trimester using thigh measurements. J Ayub Med Coll Abbottabad 2008;20:92-6.

53. Siemer J, Peter W, Zollver H, Hart N, Müller A. How good is fetal weight estimation using volumetric methods? Ultraschall Med 2008;29:377-82.

54. Chen P, Yu J, Li X, Wang Y, Chang C. Weight estimation for low birth weight fetuses and macrosomic fetuses in Chinese population. Arch Gynecol Obstet 2011;284:599-606.

55. Siemer J, Egger N, Hart N, Meurer B, Müller A, Dathe O. Fetal weight estimation by ultrasound: comparison of 11 different formulae and examiners with differing skill levels. Ultraschall Med 2008;29:159-64.

56. Souka AP, Papastefanou I, Michalitsi V, Pilalis A, Kassanos D. Specific formulas improve the estimation of fetal weight by ultrasound scan. J Matern Fetal Neonatal Med 2014;27:737-42.

57. Vieira MF, Nardozza LM, Araujo Júnior E, Guimarães Filho HA, Moron AF. [Prediction of birth weight by three-dimensional ultrasonography using fetal upper arm volume: preliminary results]. Rev Bras Ginecol Obstet 2008;30:190-5.

58. Srisantiroj N, Chanprapaph P, Komoltri C. Fractional thigh volume by three-dimensional ultrasonography for birth weight prediction. J Med Assoc Thai 2009;92:1580-5.

59. Nardozza LM, Araújo Junior E, Vieira MF, Rolo LC, Moron AF. [Estimate of birth weight using two- and three-dimensional ultrasonography]. Rev Assoc Med Bras 2010;56:204-8.

60. Nardozza LM, Vieira MF, AraujoJúnior E, Rolo LC, Moron AF. Prediction of birth weight using fetal thigh and upper-arm volumes by three-dimensional ultrasonography in a Brazilian population. J Matern Fetal Neonatal Med 2010;23:393-8.

61. Schild RL, Maringa M, Siemer J, Meurer B. Weight estimation by three-dimensional ultrasound imaging in the small fetus. Ultrasound Obstet Gynecol 200;32:168-75.

62. Lindell G, Marsál K. Sonographic fetal weight estimation in prolonged pregnancy: comparative study of two- and three-dimensional methods. Ultrasound Obstet Gynecol 2009;33:295-300.

63. Hasenoehrl G, Pohlhammer A, Gruber R, Staudach A, Steiner H. Fetal weight estimation by 2D and 3D ultrasound: comparison of six formulas. Ultraschall Med 2009;30:585-90.

64. Loannou C, Talbot K, Ohuma E, et al. Systematic review of methodology used in ultrasound studies aimed at creating charts of fetal size. BJOG 2012;119:1425-39.

65. Garza C, de Onis M. Rationale for developing a new international growth reference. Food Nutr Bull 2004;25: S5-14.

66. Villar J, Altman DG, Purwar M, Noble JA, Knight HE, Ruyan P, et al. The objectives, design and implementation of the INTERGROWTH-21st project. BJOG 2013;120:9-26.

67. Villar J, Papageorghiou AT, Pang R, Salomon LJ, Langer A, Victora C, et al. Monitoring human growth and development: a continuum from the womb to the classroom. Am J Obstet Gynecol 2015;213:494-9.

68. Papageorghiou AT, Ohuma EO, Altman DG. International standards for fetal growth based on serial ultrasound measurements: the Fetal Growth longitudinal Study of the intergrowth -21st Project. Lancet 2014;384:869-79.

69. Villar J, Cheikh IL, Victora CG, Ohuma EO, Bertino E. International standards for newborn weight, length, and head circumference by gestational age and sex: the Newborn Cross-Sectional Study of the INTERGROWTH-21st Project. Lancet 2014;384:857-68.

70. Ioannou C, Sarris I, Hoch L, Salomon LJ. Standardisation of crown-rump length measurement. BJOG 2013;120:38-41.