Consolidated and updated ultrasonographic fetal biometry and estimated fetal weight references for the Hong Kong Chinese population

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ABSTRACT

Introduction: This study aimed to construct consolidated and updated ultrasonographic fetal biometry and estimated fetal weight (EFW) references for the Hong Kong Chinese population and evaluate the extent of under- and overdiagnosis of small-for-gestational-age (SGA) and large-for-gestational-age (LGA) using these new references.

Methods: Fetal biometry and EFW references were constructed using the Generalised Additive Model for Location, Scale, and Shape, based on data from 1679 singleton pregnancies in non-smoking Chinese women. Ultrasound scans were performed at 12 to 40 weeks of gestation to measure biparietal diameter, head circumference, abdominal circumference (AC), and femur length, following standardised protocols. The rates of SGA and LGA diagnoses using the existing and updated Hong Kong fetal biometry references were compared in an independent cohort of 10 229 pregnancies.

Results: The median number of scans per gestational week between 20 and 39 weeks was 75 (interquartile range=67-83). Compared with existing references, the new AC reference would significantly (P<0.001) increase the proportions of SGA fetuses with AC measurements at <3rd and <10th percentiles from 1.7% and 6.1% to 3.4% and 10.0%, respectively. Conversely, it would significantly decrease (P<0.001) the proportions of LGA fetuses with AC at >90th and >97th percentiles from 15.0% and 4.9% to 11.5% and 3.5%, respectively.

Conclusion: Adoption of the new references, particularly for AC, may lead to increased identification of SGA cases and decreased identification of LGA cases. The proportions of these cases will be more consistent with their intended diagnostic thresholds. Further studies are needed to determine how these references impact pregnancy outcomes.

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New knowledge added by this study

- Updated biometry and estimated fetal weight (EFW) references were constructed for antenatal assessment of fetal size.
- Improved detection of small-for-gestational-age (SGA) fetuses was achieved.
- Reduced identification of fetuses classified as large-for-gestational-age was noted.

Implications for clinical practice or policy

- The updated biometry and EFW references were implemented in clinical practice by hospitals managed by the Hospital Authority in the second quarter of 2023.
- There is a need for clinicians to prepare for an increase in the number of cases requiring closer monitoring and potentially earlier interventions for SGA fetuses and a need for clear guidelines to manage the increased number of potential SGA pregnancies without overtreatment.

Introduction

Fetal biometry and estimated fetal weight (EFW) are routinely documented by sonographers and ultrasound providers during the antenatal period as early indicators of suspected or actual abnormal fetal growth. At a given gestational age (GA), small or large fetal size is often suspected when biometry measurements are below or above the reference extremes. Small for gestational age (SGA), typically defined as a fetus with an abdominal circumference (AC) or EFW <10th percentile, is associated with increased risks of stillbirth, preterm delivery, and neonatal morbidity and mortality[1,2]; this diagnosis requires more frequent ultrasound monitoring. In contrast, large for gestational age (LGA) refers to a fetus with AC or EFW >90th percentile and is associated with increased risks of macrosomia, shoulder dystocia, neonatal hypoglycaemia, caesarean delivery, and postpartum haemorrhage.[3,4] Management of an LGA fetus may include strict maternal glycaemic control in cases of gestational diabetes, early induction of labour, or scheduled caesarean delivery. Therefore, reliable reference charts for fetal biometry and size are essential in obstetric practice to optimise the use of antenatal surveillance resources, especially in public medical institutions.

The current fetal biometry references adopted by obstetricians and ultrasound providers in Hong Kong were constructed using a cohort of Hong Kong Chinese women from 1999 to 2000, based on best practices available at that time, and were published in 2008.[5] However, the clinical utility of these 2008 biometry references for identifying SGA and LGA was not evaluated until 2016 by Cheng et al,[6] who found that the percentile thresholds used to classify fetuses as SGA and LGA led to underdiagnosis of SGA and overdiagnosis of LGA. Specifically, only 4.6% of fetuses had an AC <10th percentile, whereas 13.3% had an AC >90th percentile,[6] raising concerns about the validity of the measurements in 2008[5] and whether they still reflect current fetal size, considering changes in population and socio-demographic characteristics.

The aims of the current study were to construct revised ultrasonographic fetal biometry and EFW references for the Hong Kong Chinese population, using statistical methods recommended by the World Health Organization (WHO), and to compare the rates of SGA and LGA diagnoses based on the new and existing references.

Methods

This study utilised fetal biometry data from three population cohort studies previously conducted at Prince of Wales Hospital, The Chinese University of Hong Kong.[5-7] Fetal biometry data from two of the cohorts[5,7] were used to construct the revised biometry and EFW references, while the remaining cohort[6] was used to assess the clinical utility of specific percentiles from the updated biometry references. This study followed the TRIPOD (Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis) reporting guideline.[8]

Derivation of biometry and estimated fetal weight references

The new fetal biometry references were developed using data collected from non-smoking Chinese women with viable, spontaneously conceived singleton pregnancies, recruited at 11 to 13 weeks of gestation from the general obstetric population in the years 1999-2000[5] and 2015-2016.[7] Women who consented to participate in either cohort were randomly selected to undergo a study-specific ultrasound examination of fetal size by a maternal-fetal medicine specialist at GAs ranging from 12 to 40 weeks. Gestational age at recruitment was calculated based on the first date of the last menstrual period if it corresponded to the crown-rump length measurement within a 4-day margin; otherwise, the GA was adjusted using a crown-rump length formula specific to the Chinese population.[9] Pregnancies with fetal anomalies were excluded from both cohorts.

Transabdominal ultrasounds were performed using standard commercially available transducers and machines present in the hospital, as described in the original studies.[5,7] Fetal biometric measurements, including head circumference (HC), biparietal diameter (BPD) measured in an outer-inner manner, AC, and femur length (FL) were obtained using identical standardised protocols, as previously described.[5,7] Estimated fetal weight was derived from biometric data using the formula $EFW=10^{(1.326+0.0107\times HC+0.0438\times AC+0.158\times FL-0.00326\times AC\times FL)}$, as previously published by Hadlock et al[10] and adopted

香港華人的綜合及最新超聲波胎兒生長指標及胎兒估計體重參考

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引言：本研究旨在建立香港華人的綜合及最新超聲波胎兒生長指標及胎兒估計體重參考，並使用這些新參考評估胎兒小於妊娠年齡（SGA）及胎兒大於妊娠年齡（LGA）的診斷不足及過度診斷程度。

方法：我們根據1679名不吸煙的單胎妊娠華裔婦女數據，使用廣義可加模型（GAMLSS）建立胎兒生長指標及胎兒估計體重參考，並根據標準指引，為懷孕第12至40周的婦女進行超聲波掃描，以量度胎兒的雙頂徑、頭圍、腹圍及股骨長。我們使用現有及最新的香港胎兒生長指標參考，比較10 229個獨立隊列懷孕個案的SGA及LGA診斷率。

結果：在懷孕第20至39周期間每周超聲波檢查的中位數為75次（四分位數間距=67-83）。與現有參考相比，新的腹圍參考值會顯著增加SGA胎兒在腹圍測量值低於第3百分位數及第10百分位數的比例，分別由1.7%及6.1%增加至3.4%及10.0%（P<0.001）。相反，它會明顯降低LGA胎兒在腹圍測量值超過第90百分位數及第97百分位數的比例，分別由15.0%及4.9%跌至11.5%及3.5%（P<0.001）。

結論：採用新參考（尤其是腹圍）可能導致識別更多SGA及較少LGA個案。這些個案的比例將與它們的預期診斷閾值更趨一致。未來需進行更多相關研究，以找出這些參考如何影響妊娠結果。

by the WHO.[11]

Biometry reference models for HC, BPD, AC, FL and EFW according to GA were constructed using the Generalised Additive Model for Location, Scale, and Shape (GAMLSS) package (version 5.0) in R statistical software (version 3.3.2). Best-fit models were developed in a stepwise manner, beginning with models based on the normal distribution and considering alternatives such as the Box–Cox power exponential, as appropriate. Gestational age was included as a polynomial term, and all measurements were transformed to their natural logarithm equivalent before model construction. Goodness of fit was assessed by inspecting residuals using quantile–quantile plots and worm plots to determine whether kurtosis adjustments were necessary.[12]

Biometry models were constructed for 12 to 40 weeks of gestation, whereas EFW models were constructed for 20 to 40 weeks. Final smoothing models were chosen by balancing smoothness of percentiles, goodness of fit, and model simplicity. These final models were used to calculate smoothed values for the 50th, 10th, and 90th percentiles ($Z_\alpha = \pm 1.281$), as well as the 3rd and 97th percentiles ($Z_\alpha = \pm 1.881$). Percentiles were determined using the expression $\mu \times (1+\upsilon\sigma Z_\alpha)^{1/\upsilon}$, where Z_α represents the percentile of interest and μ, υ, and σ are dependent on the time covariate (ie, GA).

Standard errors (SEs) of the 50th percentile were estimated using the expression $SE = SD\sqrt{(1+ 0.5\ Z_\alpha^2)/n}$, assuming that the SE of the percentile of interest can be expressed as a multiple of the standard deviation (SD).[13,14]

Clinical utility of the revised biometry references

The expected clinical performance of the revised references was evaluated based on the same cohort of second- and third-trimester fetal ultrasound scans previously used to assess the INTERGROWTH-21st standards.[6] This cohort consisted of biometry measurements from 10 229 fetuses, with respective median birthweight and GA at delivery of 3140 g (interquartile range [IQR]=2850-3412) and 275 days (IQR=268-281); of these fetuses, 5419 (53.0%) were male.[6] All fetal scans were performed transabdominally by either maternal-fetal medicine specialists or midwives who had passed the American Registry for Diagnostic Medical Sonography certification, using standard commercially available transducers and ultrasound machines.

To compare the relative performances of the revised and existing biometry references, Z-scores were calculated as recommended by Salomon et al.[15] Expected median and SD values were determined for each gestational week. Z-scores for each fetal parameter were then calculated using the formula: (observed value – expected median) / expected SD. These fetal parameter Z-scores were used to determine the proportion of biometry measurements in the cohort that were <10th or >90th percentiles and <3rd or >97th percentiles, with ±1.282 and ±1.881 as respective thresholds.

Results

Updated biometry references were constructed from a combined cohort of 1679 pregnancies. The median maternal age at expected date of delivery, as well as weight and height at recruitment, were 32 years (IQR=28-34), 53 kg (IQR=38.5-58.1), and 157 cm (IQR=154-161), respectively. Of the pregnancies, 892 (53.1%) were nulliparous women. Birth details were unavailable for 115 (6.8%) pregnancies, all from the cohort recruited by Leung et al,[5] which was used to construct the existing biometry reference. In the 1564 (93.2%) pregnancies with documented birth details, the median birthweight, GA at delivery, and male sex proportion were 3160 g (IQR=2900-3405), 277 days (IQR=270-283), and 830 (53.1%), respectively. The median number of scans per gestational week between 20 and 39 weeks was 75 (IQR=67-83).

The best-fitting GAMLSS for fetal biometry and EFW are reported in online supplementary Tables 1 and 2, respectively. The distribution of residuals from the fitted models approximated that of a normal standard distribution, with means of 0, variances of 1, skewness ranging from 0 to 0.1, and kurtosis ranging from 3.22 to 3.69. The Figure shows the fitted 50th, 3rd/97th, and 10th/90th smoothed percentiles.

The Table summarises the comparison of the proportions of fetuses whose biometry was assessed for fetal size above and below specific percentiles across the 10 229 pregnancies. The proportions of fetuses identified <3rd and >97th percentiles, as well as <10th and >90th percentiles, by the revised biometry references were approximately 3% and 10%, respectively, except for the FL reference.

The analysis showed that, compared with the existing AC biometry reference,[5] the revised AC biometry reference would significantly increase the proportions of fetuses with AC measurements at <3rd and <10th percentiles from 1.7% and 6.1% to 3.4% and 10.0%, respectively (both P<0.001). It would also significantly decrease the proportions of fetuses with AC measurements at >90th and >97th percentiles from 15.0% and 4.9% to 11.5% and 3.5%, respectively (both P<0.001). Compared with the existing biometry references,[5] the revised biometry references would identify greater numbers of fetuses with short FL (<3rd percentile P=0.002; <10th percentile P<0.001) and smaller HC (<3rd percentile P=0.23; <10th percentile P=0.003) at the extreme lower percentile limits.

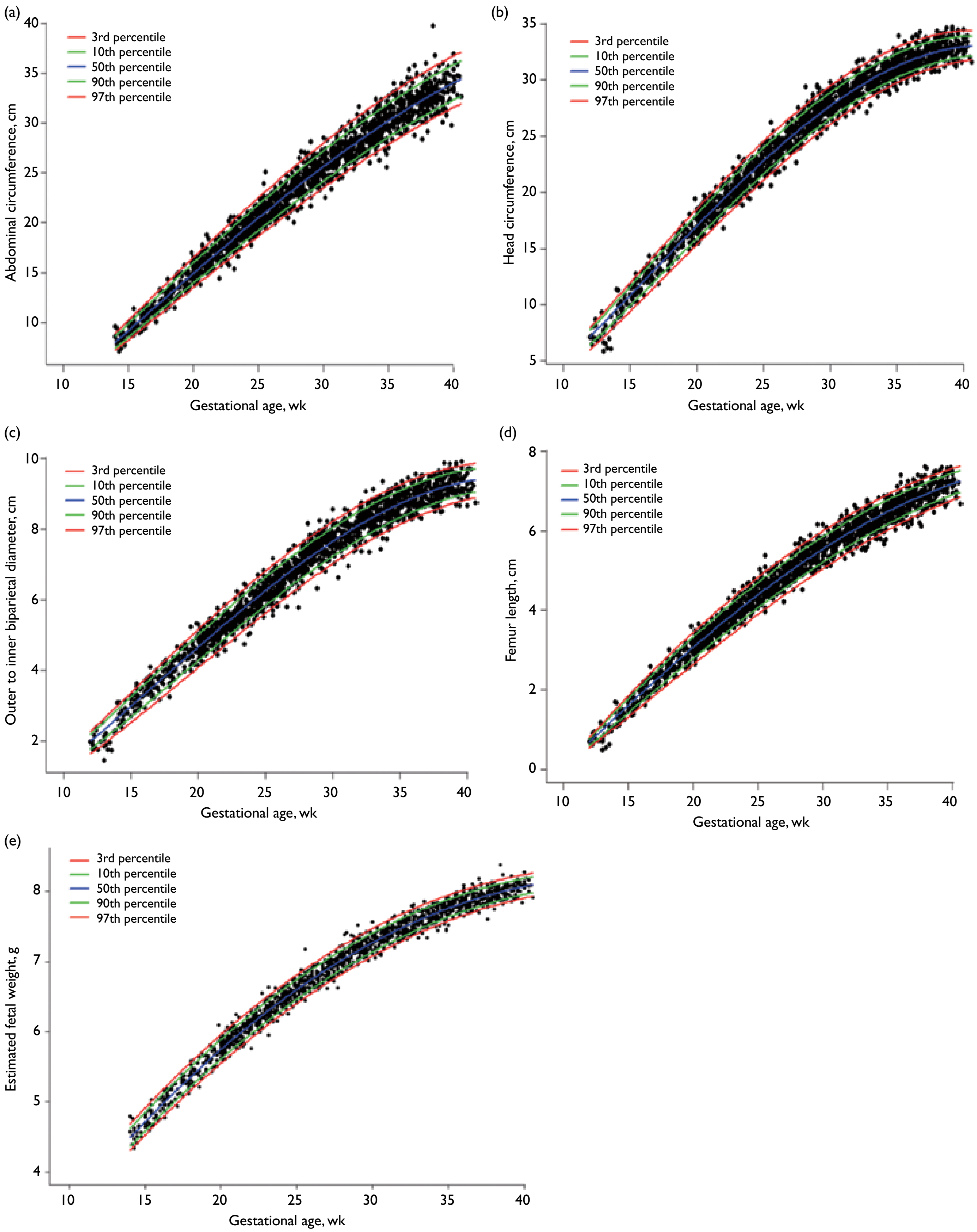

FIG. Fetal size references for the Hong Kong Chinese population, showing raw data and fitted 50th, 3rd/97th, and 10th/90th smoothed percentiles versus gestational age for (a) abdominal circumference, (b) head circumference, (c) biparietal diameter (outer to inner), (d) femur length, and (e) estimated fetal weight

TABLE. Comparison of the proportion of fetal biometry measurements among the 10 229 fetuses above and below specific percentiles for the updated local biometry reference and the existing reference[5]

	Percentile			
	<3rd	<10th	>90th	>97th
Abdominal circumference				
Existing reference[5]	1.7%	6.1%	15.0%	4.9%
Updated reference	3.4%	10.0%	11.5%	3.5%
Biparietal diameter (outer to inner)				
Existing reference[5]	3.5%	10.7%	6.5%	1.5%
Updated reference	2.7%	10.4%	6.9%	2.1%
Head circumference				
Existing reference[5]	3.1%	8.9%	8.4%	2.3%
Updated reference	3.4%	10.1%	8.0%	2.4%
Femur length				
Existing reference[5]	2.3%	7.4%	10.1%	3.0%
Updated reference	3%	10.1%	6.4%	1.5%

Discussion

Principal findings

In this study, we developed updated biometry and EFW references, then assessed how they compare with existing references created over 20 years ago.[5] These new references serve as a guide for local obstetricians and ultrasound providers, both in public institutions and private practice, to assess relative and absolute fetal sizes.

Results in the context of current knowledge

In recent years, both the INTERGROWTH-21st project[16] and the WHO11 have published biometry and EFW charts according to GA. The INTERGROWTH-21st reference was proposed as a universal standard, based on the premise that fetuses of well-nourished mothers, irrespective of ethnicity or parental characteristics, grow at similar rates.[16] Thus, a single INTERGROWTH-21st standard was recommended for assessing fetal size and growth worldwide. In contrast, the WHO suggested that its references could be customised to accommodate local populations, adjusting diagnostic thresholds for SGA and LGA to reflect population-specific characteristics.[11] Local studies assessing the suitability and impact of adopting the INTERGROWTH-21st and WHO charts have indicated that these approaches would lead to substantial misclassification of fetuses as small.[6,7,17] Similar concerns about the potential for inaccurate classification have been reported by other research groups that assessed either or both the INTERGROWTH-21st and WHO biometry charts.[18-20] Customisation of the WHO charts to fit the Hong Kong population would be comparable to developing a locally tailored biometry reference, the approach we have taken in this study.

Implications for clinical practice

The revised references had minimal impact on measurements of bony structures, such as HC, BPD, and FL. However, AC, which reflects fetal subcutaneous fat mass and nutritional status,[21] plays a greater role in calculating EFW, particularly in the third trimester.[10] The revised references should reduce the misdiagnosis of SGA and LGA, given that they are mainly based on AC and EFW. However, this change might increase the workload for obstetricians because additional scans will be needed to distinguish constitutional smallness from growth restriction.

The revised biometry and newly developed EFW references replaced the existing Leung et al's biometry references[5] previously used for antenatal management in hospitals managed by the Hospital Authority starting from the second quarter of 2023. The major clinical impact of the revised biometry references was expected to be an increase in the proportion of fetuses classified as SGA and a decrease in those classified as LGA, such that the proportions become more consistent with their intended diagnostic thresholds at the 3rd and 10th percentiles. By definition, the smallest 10% of fetuses are regarded as SGA,[1,2] and the largest 10% are considered LGA.[3,4] Although not all of these fetuses exhibit restricted growth, these classifications carry prognostic importance because they predict risks of perinatal morbidity and mortality, especially for SGA. Furthermore, fetuses classified as LGA are more likely to require induction of labour or caesarean delivery. Fetal biometry and EFW references can serve as screening tools to detect fetuses at both extremes of the growth spectrum. Further evaluation, such as assessments of growth velocity, performance of Doppler studies, and use of biophysical profiles, can help differentiate between those at high risk and those who are constitutionally small or large.[1]

One key purpose of biometry references is to reduce obstetric complications such as shoulder dystocia, stillbirth, and neonatal morbidity and mortality by improving the identification of SGA and LGA fetuses. Further studies will be needed to determine whether revision of the percentiles, particularly the AC reference, and development of a local EFW reference will show significant correlations with perinatal outcomes. However, such studies will need to be conducted over several years and require support from a funding body, considering the generally low incidence of adverse perinatal outcomes in Hong Kong pregnancies.[22] In a review of stillbirth rates from 2000 to 2020, Wong et al[23] concluded that although stillbirth rates had declined from approximately 3.3 to 2.9 per 1000 births between the first and second decades, further improvements remained necessary regarding early identification of early fetal growth restriction. This analysis indicated that 16% of all stillbirths were related to fetal growth restriction of unknown cause.[23] Whether the revised references, by classifying an increased number of fetuses as SGA, lead to improved early detection of fetal growth restriction requires prospective investigation. One approach could involve using information obtained during first-trimester Down syndrome screening to identify fetuses at increased risk of being considered SGA, followed by either longitudinal or cross-sectional assessments later in pregnancy. Leung et al[24] previously reported that low serum levels of pregnancy associated plasma protein-A and smaller fetal crown-rump length at 11 to 13 weeks of gestation were independent predictors of SGA status. More recently, Papastefanou et al[25] proposed a model for predicting SGA classification using a combination of maternal factors and the same biomarkers included in preeclampsia screening to identify potential fetuses at risk of SGA status.

Strengths and limitations

The revised biometry and newly developed EFW references were derived from a larger cohort, improving the precision of the estimated percentiles, specifically those used for clinical decision-making. By combining two cohorts with similar inclusion and exclusion criteria and using standardised ultrasound measurement protocols,[5,7] the precision of the estimated percentiles has been enhanced. The existing biometry references were based on 706 pregnancies, yielding SEs of 0.05 SD for the 10th and 90th percentiles and 0.06 SD for the 3rd and 97th percentiles. By developing the revised references from 1679 cases, we have improved the precision; the abovementioned SEs are now 0.03 SD and 0.04 SD, respectively. Additionally, consistent with biometry references reported by other groups, we used the semi-parametric GAMLSS method to concurrently model the mean, variance, skew, and kurtosis; conversely, the approach by Leung et al[5] utilised a simpler mean±k×SD model and assumed no kurtosis or skewness. The GAMLSS method is recommended by the WHO,[11,26,27] which adopted this approach during the development of its biometry and EFW references because the GAMLSS enabled more accurate prediction and smoother curves compared with earlier modelling approaches.[26] Finally, we avoided a common limitation, identified in a previous review,[28] by not retrospectively using routinely collected fetal measurements to derive biometry references—this could lead to skewed charts and inaccurate percentile limits.

A limitation of the newly revised references is that they are monoethnic because they were derived from pregnancies in Chinese women at a single hospital, which provides medical care to approximately 18% of the territory's population.[29] Hong Kong is a largely homogenous society in which approximately 92% of individuals are Han Chinese.[30] However, considering possible ethnic differences, especially when comparing East and Southeast Asians with other groups, caution may be needed when interpreting biometry and EFW measurements in other ethnic populations.[31,32]

Conclusion

We have constructed and updated ultrasonographic fetal biometry and EFW reference percentiles for the antenatal assessment of fetal size in Hong Kong Chinese singleton pregnancies. The adoption of these updated biometry percentile references, particularly regarding AC, is expected to result in an increased proportion of fetuses classified as SGA and a decreased proportion of fetuses considered LGA. The proportions of SGA and LGA cases will be more consistent with the intended diagnostic thresholds. Further prospective studies are needed to determine whether the introduction of these revised biometry and EFW reference percentiles by the hospitals of the Hospital Authority will lead to improved perinatal outcomes.

Author contributions

Concept or design: F Liu, DS Sahota.
Acquisition of data: F Liu, J Lu, AHW Kwan, L Wong.
Analysis or interpretation of data: F Liu, YK Yeung, CPH Chiu, DS Sahota.
Drafting of the manuscript: F Liu, DS Sahota.
Critical revision of the manuscript for important intellectual content: LC Poon, DS Sahota.

All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of interest

All authors have disclosed no conflicts of interest.

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Ethics approval

This is a retrospective analysis of data that were collected as part of approved studies conducted by the Joint Chinese University of Hong Kong–New Territories Cluster Clinical Research Ethics Committee, Hong Kong, for the same use and purpose (Ref Nos.: CRE-9019, CRE-2012.538, and CRE 2014.507). Informed consent was obtained from patients when the data was originally collected.

Supplementary material

The supplementary material was provided by the authors and some information may not have been peer reviewed. Accepted supplementary material will be published as submitted by the authors, without any editing or formatting. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by the Hong Kong Academy of Medicine and the Hong Kong Medical Association. The Hong Kong Academy of Medicine and the Hong Kong Medical Association disclaim all liability and responsibility arising from any reliance placed on the content. To view the file, please visit the journal online (https://doi.org/10.12809/hkmj2310910).

References

1. Lees CC, Stampalija T, Baschat A, et al. ISUOG Practice Guidelines: diagnosis and management of small-for-gestational-age fetus and fetal growth restriction. Ultrasound Obstet Gynecol 2020;56:298-312.
2. ACOG Practice Bulletin No. 227: Fetal Growth Restriction: correction [editorial]. Obstet Gynecol 2021;137:754.
3. Evidence review for large-for-gestational age baby: intrapartum care for women with existing medical conditions or obstetric complications and their babies. Evidence review Q. NICE Guideline No. 121. National Institute for Health and Care Excellence: London; 2019.
4. Macrosomia: ACOG Practice Bulletin, Number 216. Obstet Gynecol 2020;135:e18-35.
5. Leung TN, Pang MW, Daljit SS, et al. Fetal biometry in ethnic Chinese: biparietal diameter, head circumference, abdominal circumference and femur length. Ultrasound Obstet Gynecol 2008;31:321-7.
6. Cheng YK, Leung TY, Lao TT, Chan YM, Sahota DS. Impact of replacing Chinese ethnicity-specific fetal biometry charts with the INTERGROWTH-21(st) standard. BJOG 2016;123 Suppl 3:48-55.
7. Cheng YK, Lu J, Leung TY, Chan YM, Sahota DS. Prospective assessment of INTERGROWTH-21st and World Health Organization estimated fetal weight reference curves. Ultrasound Obstet Gynecol 2018;51:792-8.
8. Collins GS, Reitsma JB, Altman DG, Moons KG. Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD): the TRIPOD statement. BMC Med 2015;13:1.
9. Sahota DS, Leung TY, Leung TN, Chan OK, Lau TK. Fetal crown-rump length and estimation of gestational age in an ethnic Chinese population. Ultrasound Obstet Gynecol 2009;33:157-60.
10. Hadlock FP, Harrist RB, Sharman RS, Deter RL, Park SK. Estimation of fetal weight with the use of head, body, and femur measurements—a prospective study. Am J Obstet Gynecol 1985;151:333-7.
11. Kiserud T, Piaggio G, Carroli G, et al. The World Health Organization fetal growth charts: a multinational longitudinal study of ultrasound biometric measurements and estimated fetal weight. PLoS Med 2017;14:e1002220.
12. van Buuren S, Fredriks M. Worm plot: a simple diagnostic device for modelling growth reference curves. Stat Med 2001;20:1259-77.
13. Healy MJ. Notes on the statistics of growth standards. Ann Hum Biol 1974;1:41-6.
14. Royston P. Constructing time-specific reference ranges. Stat Med 1991;10:675-90.
15. Salomon LJ, Bernard JP, Duyme M, Buvat I, Ville Y. The impact of choice of reference charts and equations on the assessment of fetal biometry. Ultrasound Obstet Gynecol 2005;25:559-65.
16. Papageorghiou AT, Ohuma EO, Altman DG, et al. 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.
17. Lok IW, Kong MC, To WW. Updated gestational age specific birthweight reference of Hong Kong Chinese newborns and comparison with local and international growth charts. Open J Obstet Gynecol 2021;11:940-54.
18. Liu S, Metcalfe A, León JA, et al. Evaluation of the INTERGROWTH-21st project newborn standard for use in Canada. PLoS One 2017;12:e0172910.
19. Jakubowski D, Salloum D, Maciejewski M, et al. Comparison of application of Fenton, Intergrowth-21st and WHO growth charts in a population of Polish newborns. Clin Exp Obstet Gynecol 2021;48:949-54.
20. Huang TM, Tsai CH, Hung FY, Huang MC. A novel reference chart and growth standard of fetal biometry in the Taiwanese population. Taiwan J Obstet Gynecol 2022;61:794-9.
21. Gardeil F, Greene R, Stuart B, Turner MJ. Subcutaneous fat in the fetal abdomen as a predictor of growth restriction. Obstet Gynecol 1999;94:209-12.
22. Hong Kong College of Obstetricians and Gynaecologists. Territory-Wide Audit in Obstetrics and Gynaecology. 2014. Available from: https://www.hkcog.org.hk/hkcog/Download/Territory-wide_Audit_in_Obstetrics_Gynaecology_2014.pdf. Accessed 1 Apr 2023.
23. Wong ST, Tse WT, Lau SL, Sahota DS, Leung TY. Stillbirth rate in singleton pregnancies: a 20-year retrospective study from a public obstetric unit in Hong Kong. Hong Kong Med J 2022;28:285-93.
24. Leung TY, Sahota DS, Chan LW, et al. Prediction of birth weight by fetal crown-rump length and maternal serum levels of pregnancy-associated plasma protein-A in the first trimester. Ultrasound Obstet Gynecol 2008;31:10-4.
25. Papastefanou I, Wright D, Nicolaides KH. Competing-risks model for prediction of small-for-gestational-age neonate from maternal characteristics and medical history. Ultrasound Obstet Gynecol 2020;56:196-205.
26. Stasinopoulos DM, Rigby RA. Generalized Additive Models for Location, Scale and Shape (GAMLSS) in R. J Stat Softw 2007;23:1-46.
27. Borghi E, de Onis M, Garza C, et al. Construction of the World Health Organization child growth standards: selection of methods for attained growth curves. Stat Med 2006;30:247-65.
28. Ioannou 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.
29. Census and Statistics Department, Hong Kong SAR Government. District profiles (population and households). 2023. Available from: https://www.censtatd.gov.hk/en/map_ghs.html. Accessed 1 Apr 2023.
30. Race Relations Unit, Home Affairs Department, Hong Kong SAR Government. The demographics: ethnic groups. Available from: https://www.had.gov.hk/rru/english/info/demographics.htm. Accessed 1 Apr 2023.
31. Shiono PH, Klebanoff MA, Graubard BI, Berendes HW, Rhoads GG. Birth weight among women of different ethnic groups. JAMA 1986;255:48-52.
32. Kierans WJ, Joseph KS, Luo ZC, Platt R, Wilkins R, Kramer MS. Does one size fit all? The case for ethnic-specific standards of fetal growth. BMC Pregnancy Childbirth 2008;8:1.