SRYAHWA PUBLICATIONS

Open Access Journal of Gynecology and Obstetrics
ISSN: 2638-5244 | Volume 6, Issue 2, 2024
https://doi.org/10.22259/2638-5244.0602001

RESEARCH ARTICLE

Estimation of Fetal Birth Weight at Delivery: Which is More Accurate? Comparison of Ultrasound Hadlock Versus Clinical Dare's Methods across Maternal and Fetal Weight

Izyan Atiqah Zakaria[1], Debbie Teh Su Jian[2], Ainaa Syazana Mohamad[1], Nooryian Yahya[1], Rosmaliana Zulkifli[1], Rahana Abd Rahman[1], Azmawati Mohammed Nawi[3], Shuhaila Ahmad[1]

[1]*Department of Obstetrics and Gynaecology, Faculty of Medicine, National University of Malaysia, Kuala Lumpur, MY*
[2]*PJ Integrated Center for Advanced Surgery and Oncology (Picaso), Selangor, Malaysia*
[3]*Department of Public Health Medicine, Faculty of Medicine, National University of Malaysia, Kuala Lumpur, MY*

Received: 18 October 2024 Accepted: 07 November 2024 Published: 20 November 2024
Corresponding Author: Izyan Atiqah Zakaria, Department of Obstetrics and Gynaecology, Faculty of Medicine, National University of Malaysia, Kuala Lumpur, Malaysia

Abstract

Background: Accurate fetal birth weight estimation is crucial for a smooth, complication-free birthing experience. However, the rising rates of maternal obesity present significant challenges for obstetricians, frequently leading to over or underestimation that can have serious consequences.

Methods: This prospective cohort study involved 154 singleton pregnancies within a week of delivery. Fetal weight was estimated using both Dare's clinical formula and Hadlock's ultrasound formula, and these estimates were compared against actual birth weights. The mean error of measurement was analyzed across various classes of maternal body mass index (BMI) and fetal birth weight strata.

Results: The Ultrasound Hadlock's formula is significantly more accurate than the clinical Dare's formula for estimating fetal birth weight, with a mean absolute error of 186.0 g versus 441.2 g ($p<0.001$). Ultrasound accurately estimates within 10% of actual birth weight in 83.7% of cases, compared to 37.6% for clinical estimation ($p<0.001$), and remains reliable across different maternal BMIs. However, the clinical method is more accurate in predicting fetal macrosomia, with a mean absolute error of 153.3 g compared to 343.3 g for ultrasound. Increasing maternal weight gain during pregnancy is also significantly associated with higher birth weight ($p < 0.001$, $B = 0.023$).

Conclusions: Ultrasound is crucial for improving the accuracy of fetal weight estimation, particularly in obese mothers. However, clinical estimation remains valuable, especially in low-risk birth centers where ultrasound may not always be accessible.

Keywords: Birth Weight, Fetal Macrosomia, Pregnancy Complications, Ultrasound Hadlock, Dare's Formula.

1. Introduction

Estimating fetal weight was a routine obstetric assessment before delivery. Traditionally, this was done using clinical estimation, which varied depending on the operator's experience and methods used. In modern obstetrics, ultrasound is increasingly used to estimate fetal weight. This was particularly important as decisions regarding the mode and timing of delivery could be affected, especially in patients with diabetes mellitus, a previous Caesarean delivery, breech presentation, hypertensive disorders in pregnancy, and intrauterine growth restriction.

Clinical methods that were used included formulas proposed by Johnson and Tosch, Dare et al. and Dawn

Citation: Izyan Atiqah Zakaria, Debbie Teh Su Jian, Ainaa Syazana Mohamad, *et.al.* Estimation of Fetal Birth Weight at Delivery: Which is More Accurate? Comparison of Ultrasound Hadlock Versus Clinical Dare's Methods across Maternal and Fetal Weight. Open Access Journal of Gynecology and Obstetrics 2024;6(2): 01-07.

et al [1]. These formulas required simple clinical measurements such as symphysis-fundal height, abdominal girth, longitudinal diameter of the uterus, transverse diameter of the uterus, and the descent of the fetal head measured as the station. These were easy and fast measurements that could be trained and were more cost-effective compared to ultrasonography. On the other hand, ultrasonography estimates used several fetal measurements such as the biparietal diameter, head circumference, abdominal circumference, and femur length, for the algorithmic reconstruction of fetal volume of varying tissue density using Hadlock formula as one of the most commonly used [2]. However, both clinical and ultrasonography methods had their limitations, such as operator dependency and maternal obesity.

The incidence of obesity in women worldwide was found to be increasing, which had significant effects on pregnancy outcomes. Studies showed that maternal obesity was associated with higher fetal birth weight and a higher incidence of labor dystocia and shoulder dystocia [3,4] . Up to 75% of 1,637 obese mothers delivered macrosomic neonates, and there were significant associations between macrosomia and maternal and fetal complications such as uterine atony, genital tract trauma, brachial plexus injury, and clavicle fracture[5]. Therefore, it was important to provide an accurate assessment of the estimated fetal weight just before delivery to prevent associated complications for both mother and baby. This also allowed counseling by the obstetrician to the pregnant woman and shared decision-making on the best timing and mode of delivery in an attempt to reduce medicolegal implications.

The objective of this study was to compare the accuracy of estimated fetal weight between ultrasonography and clinical methods against actual birth weight. It also aimed to determine if the accuracy differed according to maternal body mass index (BMI) or actual birth weight strata of the baby.

2. Methodology

This was a prospective cohort study conducted at Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM) between 1st March 2018 to 31st August 2018. This was a tertiary center with availability of sonographers and the delivery rate was about 400 deliveries per month. Ethics approval was obtained from the Research and Ethical Committee, Faculty of Medicine Universiti Kebangsaan Malaysia (FF-2018-068). The sample size was calculated using the G*power version 3.1.9.2 [6]. To detect a minimum of 100 g mean difference in fetal weight with a standard deviation of 400g using 80% statistical power and probability of type I error of 0.05, we required a minimum of 128 subjects[4]. To accommodate a 20% loss to follow-up, the sample size was increased to 154 subjects.

Patients who fulfilled the inclusion criteria from the antenatal wards, labour ward or patient admission center (PAC) were approached to participate in the study. The inclusion criteria in this study were term, singleton pregnancy with reliable dates (sure of last menstrual period or with early dating scan by 20 weeks) and expected to deliver within a week. The exclusion criteria were multiple pregnancy, polyhydramnios (amniotic fluid index >25), oligohydramnios (amniotic fluid index <5), intrauterine demise, presence of abnormal uterus, fibroid, adnexal mass like ovarian cyst and fetal anomaly. Patients who provided written consent were recruited into the study.

Upon recruitment, clinical data such as age, parity, gestational age and maternal BMI were recorded. To minimize bias, clinical measurement was performed prior to ultrasound measurement. Clinical measurements were done by the same Obstetrics & Gynaecology registrar with clinical experience of 6 years. The patient was asked to empty her bladder then the symphysio-fundal height and abdominal girth in the relaxed uterus were measured using a flexible, nonelastic standard measuring tape. Estimated fetal weight was calculated by multiplying the symphysio-fundal height (SFH) and abdominal girth (AG) according to the formula proposed by Dare et al [7]. This formula was chosen as it had specific definitions to the measurements hence easily performed and reproducible. Ultrasound measurement was performed by the same sonographer with more than 5 years of experience. Fetal weight was estimated using the Hadlock's formula using measurements of biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL)[8]. The amniotic fluid index (AFI) was also measured to exclude polyhydramnios or oligohydramnios as these were the exclusion criterias.

All of the measurements were tabulated in a datasheet and compared with the actual birth weight after delivery which was collected from the patient's case notes. Accuracy was measured as absolute error, absolute percentage error and percentage of cases within 10% of actual birth weight. Mean and standard deviation were calculated and compared between clinical and ultrasound methods. All statistical

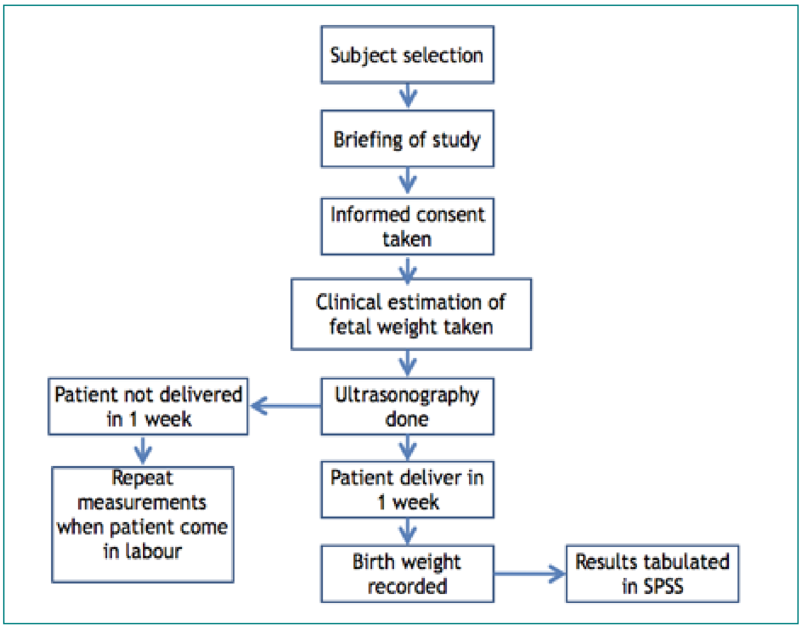

Figure 1. *Flowchart showing the research methodology*

analyses were performed using Statistical Package for Social Sciences (SPSS) with p-values of less than 0.05 considered as statistically significant. The study flowchart was described in Figure 1.

3. Results

Table 1 showed the characteristics of the study participants. The mean age was 33 years old and mean gestational age at delivery was 38 weeks. Nearly half delivered via elective Caesarean sections (47.4%, n=73) while more than half of the participants were multiparous (69.5%, n=107) (Table 1).

Table 1. *Demographics of all study participants, n=154*

Characteristics	Median	Range	Mean (SD)
Maternal age (years)	33	20-46	33.45 (4.69)
Parity	1	0-7	1.3 (1.3)
Maternal body weight (kg)	73	46.5-118	72.8 (12.09)
Gestational age (weeks)	38	37-40	38.1 (0.93)
Maternal weight gain (kg)	11	0-31	11.7 (5.55)

When compared according to actual birth weight classification, the maternal characteristics were not significantly different except for the maternal body weight. It was observed that heavier mothers gave birth to heavier babies (Table 2).

Table 2. *Maternal characteristics according actual birth weight classification*

Maternal characteristics	Low birth weight, <2.5kg (n=17)	Normal birth weight, 2.5-4kg (n=134)	Macrosomic baby, >4kg (n=3)	p value (ANOVA)
Age (years)	31.1 (3.23)	33.7 (4.8)	35.3 (3.51)	0.078
Parity	1.1 (1.7)	1.3 (1.3)	2.3(0.6)	0.373
Body weight (kg)	62.9 (12.7)	73.8 (11.5)	83.0 (2.64)	0.001
Gestational age	37.7 (0.91)	38.1(0.93)	38.3 (0.58)	0.147

Furthermore, maternal weight gain was plotted against actual fetal birth weight as shown in Figure 2. Simple linear regression showed that increasing maternal weight gain during pregnancy was associated with a higher actual birth weight of the baby and the association was statistically significant (p-value <0.001, B = 0.023). While the correlation was not strong (r = 0.292), the regression model loosely implied that every 1 kg increase in maternal weight corresponded to an increase in the baby's birth weight by 2.3 g (Figure 2).

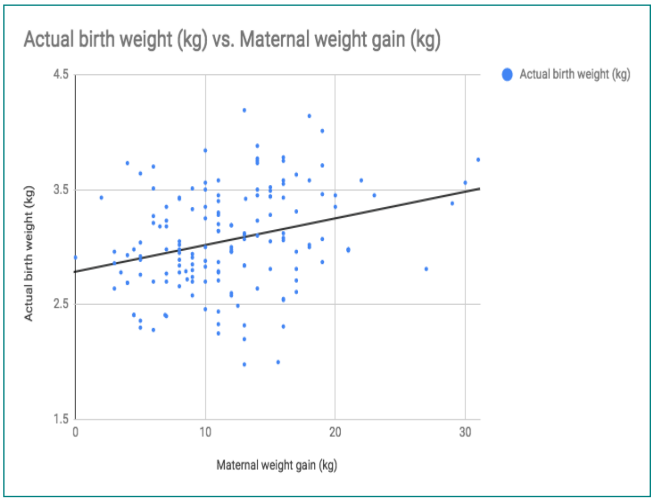

Figure 2. *Scatter plot diagram of maternal weight gain and actual birth weight.*

The accuracy between clinical and ultrasound methods for all patients were given in Table 3. Both clinical and ultrasound methods were acceptable means to estimate fetal birth weight as both had an absolute error of 15% or less (15% for clinical and 6% for ultrasound, $p<0.01$). However, ultrasound measurement was more accurate as it had a lower absolute error than clinical measurement which was statistically significant. The percentage of cases estimated within 10% of actual birth weight was also significantly higher by ultrasound compared to clinical methods (Table 3).

Table 3. *Comparison of accuracy between clinical and ultrasound methods for EFW measurement (n=154)*

Calculated parameters	Clinical Mean (S.D)	Ultrasound Mean (S.D)	p-value
Absolute error (g)	441.2 (303.10)	186.0 (152.10)	<0.001
Absolute error in percentage (%)	15.07 (11.24)	5.99 (5.03)	<0.001
Accuracy within 10% of actual birth weight (%)	37.6	83.7	<0.001

Further analysis according to maternal body mass index also found that ultrasound had lower absolute errors compared to clinical methods for all classes of maternal BMI which were statistically significant, as shown in Table 4.

Table 4. *Comparison of accuracy between clinical and ultrasound methods according to classes of maternal body mass index*

Maternal body mass index (kg/m2)	Absolute error in g (mean, s.d)		
	Clinical	Ultrasound	p-value^
All (n=154)	441.2 (303.10)	186.0 (152.10)	<0.001
Normal (n=19)	249.26 (159.37)	167.37 (154.52)	0.11
Overweight (n=62)	343.71 (245.06)	206.77 (157.18)	<0.001
Obese (n=73)	893.0 (259.40)	131.8 (102.00)	<0.001

^*Analysis using independent t-test, $p<0.05$ considered statistically significant*

However, when stratified according to actual birth weight strata, the clinical method was most accurate when estimating a macrosomic baby, as shown by the lowest absolute error in Table 5. Nevertheless, for normal and low birth weight babies, ultrasound had lower absolute error compared to clinical methods (Table 5).

Table 5. *Comparison of accuracy between clinical and ultrasound method according to classes of actual birth weight*

Actual baby birth weight (g)	Absolute error (g) mean, (s.d)		
	Clinical	Ultrasound	p-value
Low birth weight <2.5kg (n=17)	533.59 (305.11)	175.88 (210.18)	0.0004
Normal birth weight 2.5-4kg (n=134)	436.01 (302.05)	183.81 (141.37)	<0.001
Macrosomia >4kg (n=3)	153.33 (144.23)	343.33 (223.01)	0.28

4. Discussion

This was a prospective cohort study that assessed the accuracy of clinical Dare's formula and ultrasound's Hadlock method of birth weight estimation for the same group of population within a week of delivery. The above results showed that ultrasound measurement was more accurate than clinical methods to estimate fetal birth weight and the accuracy of ultrasound was not affected by maternal body mass index. Furthermore, clinical estimation using Dare's formula overestimated fetal birth weight, especially for more obese mothers. However, in estimating macrosomic babies, clinical measurement was found to be most accurate as compared to that of ultrasound. In addition, the study also showed a direct correlation between maternal body weight, gestational weight gain, and actual birth weight. This has implications for future research and interventions targeting obese mothers and/or preventing labour complications due to unexpected fetal macrosomia.

Similar studies have been conducted elsewhere with varying results. A study done among 200 women in Nigeria found that the clinical method was comparable to the ultrasound method in estimating fetal weight at term in singleton pregnancies. The mean absolute error for clinical estimate was higher but not significantly different compared to that of ultrasound (362 ± 307 g versus 293 ± 313 g, p=0.205). Accuracy within 10% of actual birth weight was also reported to be 69.5% for the clinical method and 72% for the ultrasound method. As clinical estimation is comparable to that of ultrasound, their recommendation was for clinical estimation using Dare's formula to be routinely taught to medical personnel [9]. Another larger study done among 1717 women in Assaf-Harofeh Medical Centre, Israel showed the clinical estimate was more accurate than the ultrasound estimate. The mean of all error terms were significantly smaller for the clinical method compared to the ultrasound method. Accuracy within 10% of actual birth weight was 71.5% for clinical and 68.7% for ultrasound. When analysed according to different birth weight strata, it was observed that clinical estimates were more accurate in babies weighing more than 2500 g [10]. Another study involving 525 parturient also concluded that the clinical method using Johnson's formula had a higher correlation to actual birth weight compared to the ultrasound method [11].

Conversely, a recent study done in Nepal reported ultrasound estimation was more accurate and consistent in different periods of gestation. The clinical mean error was significantly higher at 415.65 ± 283.54 g while the ultrasound mean error was 312.40 ± 252.12 g which was statistically significant (p=0.007) [12]. A study done in Germany on 204 women showed that ultrasonographic estimation was more accurate as compared to clinical methods if performed by trained ultrasound examiners [13]. Another study done in India also concluded that the ultrasound method was superior to the clinical method in estimating fetal weight at term [14].

This disparity could be partly explained by advancements in ultrasound technology in recent years, which have contributed to higher accuracy in fetal weight estimation in recent studies compared to those conducted in the 1990s. One such development included measurement of fetal thigh volume in addition to standard fetal biometry which showed a higher accuracy of prediction of birth weight using ultrasound, as reported in a study [15]. Another explanation was due to the increasing prevalence of maternal obesity which reduced the accuracy of estimation both by ultrasound and clinical methods. For example, several other studies also showed a similar trend of fetal weight estimation being less accurate in women with higher BMI [13,16]. The discrepancy in abdominal girth measurement could also contribute to the inaccuracy of clinical estimation found in higher maternal BMI. It was found that Asians had a higher fat distribution compared to Caucasians, with adipose tissue deposits in two distinct anatomical depots: visceral adipose tissue and subcutaneous adipose tissue. This increased their abdominal girth [17,18].

One of the main reasons to estimate the fetal weight at term was to suspect macrosomic babies to avoid adverse perinatal outcomes following obstructed labour or shoulder dystocia. As shown in this study, clinical estimation was more accurate in detecting a macrosomic baby compared to ultrasound; hence, the clinical method was still reliable for screening for macrosomic babies, especially in low-risk birth centers or in district hospitals where ultrasound was not available. Another study done in Nepal also showed clinical methods had better diagnostic value in detecting babies > 3500g. The study reported that bigger babies were slightly better identified by clinical method (AUC- 0.732, CI- 0.64-0.84) than by ultrasound method (AUC-0.712, CI-0.61-0.81) as determined by the area under the curve ROC method [19].

Concerning maternal weight, a study done in Nigeria also showed that mean actual birth weight increased consistently with the rise in maternal weight, as similarly found in this study [9]. The same finding was also seen in a Chinese study where it was observed that mothers who were overweight and obese had a higher risk of having babies who are macrosomic (OR 1.7, 95% CI 1.2–2.6) and large-for-gestational-age (LGA) (OR 1.7, 95% CI 1.1–2.5) compared with women of normal weight [20]. Another large study also found that higher pre-pregnancy BMI was more strongly associated with LGA babies compared to high gestational weight gain [21]. While several other studies reported that both pre-pregnancy maternal obesity and excessive gestational weight gain were associated with LGA and higher birth weight[22,24].

Following these findings, emphasis on achieving the ideal BMI before embarking on pregnancy and nutritional plan during pregnancy should be individualized according to pre-pregnancy BMI to achieve appropriate gestational weight gain. Guidelines on appropriate gestational weight gain according to BMI were initially described by the US Institute of Medicine (IOM) [25]. A recent meta-analysis showed that non-compliance with IOM guidelines had a strong association with adverse pregnancy outcomes such as a higher risk of SGA for suboptimal weight gain and a higher risk of LGA for excessive weight gain [26]. However, several studies suggested that optimal gestational weight gain may differ for Asian populations [27,28]. A study done in Singapore among multiracial women suggested that the appropriate gestational weight gain according to the pre-pregnancy BMI category, to be 19.5 kg (range, 12.9 to 23.9) for underweight, 13.7 kg (7.7 to 18.8) for normal weight, 7.9 kg (2.6 to 14.0) for overweight and 1.8 kg (−5.0 to 7.0) for obese women [29]. This could be implemented in our population as the women studied were of similar ethnicity and physique. Furthermore, obese women should be classified as high-risk pregnancies and should be delivered in obstetrician-led centers where ultrasound is available.

5. Conclusion

The present study showed that estimation of fetal birth weight at or near delivery using ultrasound was more accurate than clinical estimation using Dare's formula for singleton pregnancies in our population. The accuracy of clinical estimation was reduced in association with maternal obesity but not for ultrasound estimation. Therefore, in women who are overweight or obese, ultrasound estimation should be routinely used as it is more accurate. However, clinical estimation using Dare's formula is useful in detecting macrosomic babies and easily reproducible and should be used in low-risk birth centers or district hospitals especially when ultrasound is not available.

5.1 Statement of Significance

5.1.1 Problem or Issue

Rising maternal obesity complicates accurate fetal birth weight estimation, leading to increased risk of birth complications due to misestimations.

5.1.2 What is Already Known

Recent research highlights the challenges of estimating fetal weight in obese mothers and indicates varying accuracy of existing methods such as Dare's clinical formula and Hadlock's ultrasound formula.

5.1.3 What this Paper Adds

Incorporating insights from the latest studies, this paper reaffirms that Hadlock's ultrasound formula is significantly more accurate than Dare's clinical formula across different maternal BMI categories. It also demonstrates the clinical method's superior performance in predicting fetal macrosomia. The findings stress the importance of using ultrasound for accurate fetal weight estimation in obese mothers, improving outcomes in both high and low-resource settings.

6. References

1. Mukherjee, P., Goswami, S. & Kumari, A. Comparative Study of Various Methods of Fetal Weight Estimation in Term Pregnancy. *Journal of South Asian Federation of Obstetrics and Gynaecology* 5, 22–25 (2013).
2. Anderson, N. G., Jolley, I. J. & Wells, J. E. Sonographic estimation of fetal weight: comparison of bias, precision and consistency using 12 different formulae. *Ultrasound in Obstetrics & Gynecology* 30, 173–179 (2007).
3. Linné, Y. Effects of obesity on women's reproduction and complications during pregnancy. *Obesity Reviews* 5, 137–143 (2004).
4. Yazdani, S., Yosofniyapasha, Y., Nasab, B. H., Mojaveri, M. H. & Bouzari, Z. Effect of maternal body mass index on pregnancy outcome and newborn weight. *BMC Res Notes* 5, 34 (2012).
5. Najafian, M. & Cheraghi, M. Occurrence of Fetal Macrosomia Rate and Its Maternal and Neonatal Complications: A 5-Year Cohort Study. *ISRN Obstet Gynecol* 2012, 1–5 (2012).

6. Faul, F., Erdfelder, E., Lang, A.-G. & Buchner, A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods* 39, 175–191 (2007).
7. Dare, F. O., Ademowore, A. S., Ifaturoti, O. O. & Nganwuchu, A. The value of symphysio-fundal height/abdominal girth measurements in predicting fetal weight. *International Journal of Gynecology & Obstetrics* 31, 243–248 (1990).
8. Hadlock, F. P., Harrist, R. B., Sharman, R. S., Deter, R. L. & Park, S. K. Estimation of fetal weight with the use of head, body, and femur measurements—A prospective study. *Am J Obstet Gynecol* 151, 333–337 (1985).
9. Njoku, C. *et al.* Determination of Accuracy of Fetal Weight Using Ultrasound and Clinical Fetal Weight Estimations in Calabar South, South Nigeria. *Int Sch Res Notices* 2014, 970973 (2014).
10. Sherman, D. J. *et al.* A Comparison of Clinical and Ultrasonic Estimation of Fetal Weight. *Obstetrics & Gynecology* 91, 212–217 (1998).
11. Vaz, A. *et al.* Clinical and sonographic estimation of fetal weight and correlation with the birth weight: a research article. *Int J Reprod Contracept Obstet Gynecol* 8, 3595 (2019).
12. Joshi, A., Panta, O. & Sharma, B. Estimated Fetal Weight: Comparison of Clinical Versus Ultrasound Estimate. *J Nepal Health Res Counc* 15, (2017).
13. Lanowski, J. S. *et al.* Ultrasound versus Clinical Examination to Estimate Fetal Weight at Term. *Geburtshilfe Frauenheilkd* 77, 276–283 (2017).
14. Annapurna, K., Rama, C. & Ramamani, C. A Comparative study of Fetal Weight estimation at term by clinical method and ultrasound method and after delivery. *Indian J Appl Res* 5, 118–123 (2015).
15. Sharma, K. A. *et al.* Two-dimensional fetal biometry versus three-dimensional fractional thigh volume for ultrasonographic prediction of birthweight. *International Journal of Gynecology & Obstetrics* 145, (2019).
16. Fox, N., Bhavsar, V., Saltzman, D., Rebarber, A. & Chasen, S. Influence of Maternal Body Mass Index on the Clinical Estimation of Fetal Weight in Term Pregnancies. *Obstetrics and gynecology* 113, 641–645 (2009).
17. Straughen, J. K., Trudeau, S. & Misra, V. K. Changes in adipose tissue distribution during pregnancy in overweight and obese compared with normal weight women. *Nutr Diabetes* 3, (2013).
18. Deurenberg, P., Deurenberg-Yap, M. & Guricci, S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. *Obesity Reviews* 3, 141–146 (2002).
19. Joshi, A., Panta, O. & Sharma, B. Estimated Fetal Weight: Comparison of Clinical Versus Ultrasound Estimate. *J Nepal Health Res Counc* 15, (2017).
20. Zhao, R., Xu, L., Wu, M. L., Huang, S. H. & Cao, X. J. Maternal pre-pregnancy body mass index, gestational weight gain influence birth weight. *Women and Birth* 31, e20–e25 (2018).
21. Heude, B. *et al.* Pre-Pregnancy Body Mass Index and Weight Gain During Pregnancy: Relations with Gestational Diabetes and Hypertension, and Birth Outcomes. *Matern Child Health J* 16, 355–363 (2012).
22. Li, N. *et al.* Maternal prepregnancy body mass index and gestational weight gain on pregnancy outcomes. *PLoS One* 8, (2013).
23. Nohr, E. A. *et al.* Pregnancy outcomes related to gestational weight gain in women defined by their body mass index, parity, height, and smoking status12. *Am J Clin Nutr* 90, 1288–1294 (2009).
24. Hedderson, M. *et al.* Pregnancy Weight Gain and Risk of Neonatal Complications: Macrosomia, Hypoglycemia, and Hyperbilirubinemia. *Obstetrics and gynecology* 108, 1153–1161 (2006).
25. Rasmussen, K. M. & Yaktine, A. L. Committee to Reexamine IOM Pregnancy Weight Guidelines. *Food and Nutrition Board, Board on Children, Youth and Families, Institute of Medicine, National Research Council: Weight Gain During Pregnancy: Reexamining the Guidelines* 71–110 (2009).
26. Goldstein, R. F. *et al.* Association of Gestational Weight Gain With Maternal and Infant Outcomes: A Systematic Review and Meta-analysis. *JAMA* 317, 2207–2225 (2017).
27. WONG, W., TANG, N. L. S., LAU, T. K. & WONG, T. W. A New Recommendation for Maternal Weight Gain in Chinese Women. *J Am Diet Assoc* 100, 791–796 (2000).
28. Ota, E. *et al.* Maternal body mass index and gestational weight gain and their association with perinatal outcomes in Viet Nam. *Bull World Health Organ* 89, 127 (2011).
29. Ee, T. X. *et al.* Determining optimal gestational weight gain in a multiethnic Asian population. *Journal of Obstetrics and Gynaecology Research* 40, 1002–1008 (2014).