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Fetal ultrasound estimated weight and correlation to Brazilian newborn weight

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Abstract

Background: To compare the best fetal weight formula with different biometric tables on the weight of Brazilian newborns. **Methods:** This observational study has tested the performance of different common fetal weight formulas and biometric tables. Weight estimates were performed by the methods of Warsof *et al.* (1977), Shepard *et al.* (1982), Hadlock *et al.* (1985), Furlan *et al.* (2012) and Stirnemann *et al.* (2017). The biometric tables selected were the following: Snijders and Nicolaides (1994), Hadlock *et al.* (1984), Papageorghiou *et al.* (2014) and Kiserud *et al.* (2016) and correlated to Pedreira *et al.* (2011) database, which was considered the gold standard. Statistical analyses were performed using the mean relative error, average absolute error and the Pearson correlation coefficient (r). **Results:** The best r was found when using the Snijders and Nicolaides (1994) biometric table with weight formula by Stirnemann *et al.* (2017). The average relative error was lower when using weight formula by Shepard *et al.* (1982) with biometric tables by Snijders and Nicolaides (1994), Papageorghiou *et al.* (2014) or Kiserud *et al.* (2016). On average, absolute error, the lowest r was obtained for the Furlan *et al.* (2012) weight formula and the Papageorghiou *et al.* (2014) biometric table. **Conclusions:** The best correlation was found for biometric table by Snijders and Nicolaides (1994) and fetal weight formula calculation for the estimation of Brazilian newborn weight by Stirnemann *et al.* (2017).

Introduction

Adverse events in the process of fetal growth can lead to consequences at later times and the extent of the damage depends on the nature, duration and severity. Two crucial determinants of fetal growth are the pregnancy duration and the fetal weight at a specific gestational age⁽¹⁾.

As weight is easy to measure at birth, it is used as an indicator of fetal growth, and is included in the comparative statistics on perinatal health improvements. There is a wide variety of normal birth weights within a specific population and between distinct populations. The factors that determine birth weight are not necessarily the same in different populations. It is a consensus that the maternal environment is extremely important for proper fetal growth and is influenced by genetic factors, biological potential and several environmental, fetal and placental regulators and modulating factors⁽²⁾.

Among the parameters used in newborn evaluation, the neonatal birth weight is an important variable that predicts neonatal morbidity and mortality. The association between prematurity, low birth weight and neonatal mortality/morbidity is well established⁽³⁾. This statement makes it clear that fetal weight calculation is an important factor in obstetric practice, as this is often decisive in continuing or interrupting high risk pregnancies.

Ultrasound, a technique that depends on equipment and specialized human resources, is the most important method for estimating fetal weight. However, even with adequate technology, the estimated fetal weight is less accurate in cases of very low birth weight and a macrosomic fetus⁽⁴⁾. Several formulas were created by different authors for estimating fetal weight from biometric measures, which include biparietal diameter (BPD), head circumference (HC), femur length (FL) and abdominal circumference (AC). Hadlock *et al.*⁽⁵⁾ showed that there is a need for at least three fetal compartment measurements: BPD or HC to indicate head growth, AC to indicate body growth, and finally the FL to estimate the height growth index.

Tab. 1. Authors and their respective estimated fetal weight formulas

Author	Formula
Warsof <i>et al.</i> ⁽⁸⁾	$\text{Log}_{10}(\text{BW}) = 0.144 * \text{BPD} + 0.032 * \text{AC} - 0.000111 * \text{AC} * \text{BPD} - 1.599$
Shepard <i>et al.</i> ⁽⁹⁾	$\text{Log}_{10}(\text{BW}) = 0.166 * \text{BPD} + 0.046 * \text{AC} - 0.002646 * \text{AC} * \text{BPD} - 1.7492$
Hadlock <i>et al.</i> ⁽¹⁰⁾	$\text{Log}_{10}(\text{BW}) = 1.3596 - 0.00386 * \text{AC} * \text{FL} + 0.0064 * \text{HC} + 0.0424 * \text{AC} + 0.174 * \text{FL} + 0.00061 * \text{BPD} * \text{AC}$
Hadlock <i>et al.</i> ⁽⁵⁾	$\text{Log}_{10}(\text{BW}) = 1.326 - 0.00326 * \text{AC} * \text{FL} + 0.0107 * \text{HC} + 0.00061 * \text{AC} + 0.158 * \text{FL}$
Furlan <i>et al.</i> ⁽¹¹⁾	$\text{EFW} = -8.277 + 2.146 * \text{BPD} * \text{AC} * \text{FL} - 2.449 * \text{FL} * \text{BPD}^2$
Stirnemann <i>et al.</i> ⁽¹²⁾	$\text{Log}(\text{EFW}) = 5.084820 - 54.06633 * (\text{AC}/100)^3 - 95.80076 * (\text{AC}/100)^3 * \text{Log}(\text{AC}/100) + 3.136370 * (\text{HC}/100)$

The formulas for estimating fetal weight were built by a regression analysis based on birth weight and biometric parameters at different gestational ages. Substantial bias occurs in the biometric parameters at each gestational age between different authors, and thus the value calculated as weight, using a given formula with different biometric authors, will give the same result, but when distributed on a normal curve it will occur at different percentile positions, creating a confusion factor about fetal growth normality⁽⁶⁾.

In Brazil, Pedreira *et al.*⁽⁷⁾ measured birth weight at each gestational age, based on nearly 8 million observations in an ethnically mixed population. This was the first comprehensive study aiming to be a reference for pediatricians in newborn care. This study was based on data collected from Brazilian birth certificate records including 22 to 42 weeks of gestational age, generating a fetal curve weight.

The aim of this study was to use the Pedreira *et al.*⁽⁷⁾ study as gold standard for Brazilian population comparing their results to other ultrasound national and international biometric tables and calculation formulas.

Methods

We conducted an observational study using formulas and tables which were selected by their importance in the international literature. This study was approved by the Ethic Committee of Federal University of Santa Catarina (UFSC). For fetal estimation weight, we used the formula of Warsof *et al.*⁽⁸⁾, Shepard *et al.*⁽⁹⁾, Hadlock *et al.*⁽¹⁰⁾, Furlan *et al.*⁽¹¹⁾ and Stirnemann *et al.*⁽¹²⁾. Biometric measurements were derived from the following tables: Snijders and Nicolaides⁽¹³⁾, Hadlock *et al.*⁽⁵⁾, Kiserud *et al.*⁽¹⁴⁾ and Papageorghiou *et al.*⁽¹⁵⁾. The 50th percentile calculation value was used in all biometric tables, thus creating weight calculation formulas and 50th percentiles expressed in grams. These results were compared with the Pedreira *et al.*⁽⁷⁾ average male and female 50th percentile weights expressed in grams. Table 1 shows the authors and their respective formulas used in the present study.

The fetal weight calculation was found by mixing different formulas and different biometrics tables. The data were plotted in a standard Excel 2011 program table (Microsoft Corp., Redmond, WA, USA). Statistical analyses were performed using the mean relative error (standard weight – estimated weight), average absolute error ((standard weight – estimated weight)/standard weight) and the Pearson correlation coefficient (r) with dispersion graphics using 2011 Excel statistical function calculations.

Results

The differences between the newborn weights and calculated estimated weight in the different tables and different

Tab. 2. Relative error (in grams) between different tables and different biometric weight calculation formulas

Formula/Biometry	Snijders and Nicolaides ⁽¹³⁾	Papageorghiou <i>et al.</i> ⁽¹⁵⁾	Hadlock <i>et al.</i> ⁽⁵⁾	Kiserud <i>et al.</i> ⁽¹⁴⁾
Hadlock <i>et al.</i> ⁽¹⁰⁾	0.01	0.01	0.01	0.01
Hadlock <i>et al.</i> ⁽⁵⁾	0.01	0.01	0.01	0.01
Warsof <i>et al.</i> ⁽⁸⁾	0.01	0.01	0.01	0.01
Shepard <i>et al.</i> ⁽⁹⁾	0.00	0.00	0.01	0.00
Furlan <i>et al.</i> ⁽¹¹⁾	0.01	0.01	0.01	0.01
Stirnemann <i>et al.</i> ⁽¹²⁾	0.00	0.01	0.00	0.00

Tab. 3. Absolute error (in grams) between different tables and different biometric weight calculation formulas

Formula/Biometry	Snijders and Nicolaides ⁽¹³⁾	Papageorghiou <i>et al.</i> ⁽¹⁵⁾	Hadlock <i>et al.</i> ⁽⁵⁾	Kiserud <i>et al.</i> ⁽¹⁴⁾
Hadlock <i>et al.</i> ⁽¹⁰⁾	-8	3	-10	-10
Hadlock <i>et al.</i> ⁽⁵⁾	2	7	-10	-8
Warsof <i>et al.</i> ⁽⁸⁾	10	2	4	-4
Shepard <i>et al.</i> ⁽⁹⁾	20	-21	-5	-29
Furlan <i>et al.</i> ⁽¹¹⁾	12	0	-13	-13
Stirnemann <i>et al.</i> ⁽¹²⁾	3	3	-7	-10

Tab. 4. Pearson correlation coefficients between different tables and different biometrics weight calculation formulas using Brazilian newborn as gold standard (Pedreira *et al.*⁽⁷⁾)

Formula/Biometry	Snijders and Nicolaides ⁽¹³⁾	Papageorghiou <i>et al.</i> ⁽¹⁵⁾	Hadlock <i>et al.</i> ⁽⁵⁾	Kiserud <i>et al.</i> ⁽¹⁴⁾
Hadlock <i>et al.</i> ⁽¹⁰⁾	0.997745838	0.995990300	0.996151154	0.994035237
Hadlock <i>et al.</i> ⁽⁵⁾	0.997523283	0.995894516	0.995958968	0.994255142
Warsof <i>et al.</i> ⁽⁸⁾	0.997627969	0.996870789	0.996436453	0.992502405
Shepard <i>et al.</i> ⁽⁹⁾	0.997432215	0.996879997	0.996473888	0.992268808
Furlan <i>et al.</i> ⁽¹¹⁾	0.996447817	0.995783331	0.995528994	0.994303123
Stirnemann <i>et al.</i> ⁽¹²⁾	0.998840641	0.995005850	0.996191769	0.992300737

biometric weight calculation formulas were studied by the average relative error and absolute error average.

The relative error: we observed that the formulas by Shepard *et al.*⁽⁹⁾ and Stirnemann *et al.*⁽¹²⁾ and the biometry by Snijders and Nicolaides⁽¹³⁾, Kiserud *et al.*⁽¹⁴⁾ and Papageorghiou *et al.*⁽¹⁵⁾ had the lowest errors, as shown in Tab. 2.

The absolute error: we observed that the formula by Furlan *et al.*⁽¹¹⁾ and biometry by Papageorghiou *et al.*⁽¹⁵⁾ had the smallest errors (zero), as shown in Tab. 3.

In the Pearson correlation coefficient (r) analyses, we noticed that the best correlation was not coincident in various formulas of the calculation of estimated weight, as shown in Tab. 4.

Figure 1, Fig. 2, Fig. 3 and Fig. 4 show the weight behavior by gestational age, linear dispersion and the best Pearson correlation coefficient. The absolute error analysis between biometric tables and weight calculation formulas in which we observed the lowest error was between Furlan *et al.*⁽¹¹⁾ and Papageorghiou *et al.*⁽¹⁵⁾. The best Pearson correlation coefficient was between Snijders and Nicolaides⁽¹³⁾ biometric table and Stirnemann *et al.*⁽¹²⁾ weight formula ($p = 0.998840641$). The relative error was lower using Shepard *et al.*⁽⁹⁾ and Stirnemann *et al.*⁽¹²⁾ weight formulas with Snijders and Nicolaides⁽¹³⁾, Papageorghiou *et al.*⁽¹⁵⁾, and Kiserud *et al.*⁽¹⁴⁾ biometric tables. On average, the best

Pearson correlation coefficient was between Stirnemann *et al.*⁽¹²⁾ weight formula and Snijders and Nicolaides⁽¹³⁾ biometric table.

Discussion

The estimated fetal weight by ultrasound at different gestational ages is extremely important for monitoring of macrosomia or fetal growth restriction. Lubchenco *et al.*⁽¹⁶⁾ proposed a table which is still widely used by pediatricians to rank fetuses as normal, small or large for gestational age. This table was constructed from 5635 living newborns from 24 to 42 gestational weeks in the period between 1948 and 1961, and newborns with abnormalities and those of uncertain gestational age were excluded. The authors reported premature births related to non-physiological causes, which could interfere with the weight, as study limitation. The creation of fetal estimated weight formulas by ultrasound includes birth weight, so this bias is part of the weight formula calculation. Lubchenco *et al.*⁽¹⁶⁾ created a fetal weight table by gestational age with percentiles and did not draft the fetal estimated weight formula. The importance of the present study was to describe which fetal weight formula and biometric table will result in the lowest error for Brazilian fetal weight. In the future, the objective will be to compare these formula and table with Lubchenco *et al.*⁽¹⁶⁾ to assess the possible application by pediatricians and obstetricians in the classification of normal and abnormal fetal weight. More studies to find the best correlation

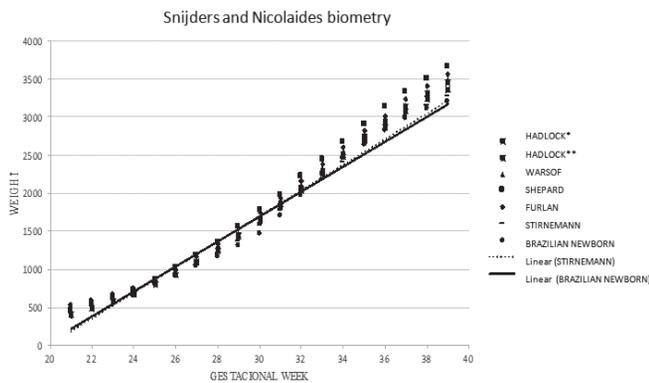


Fig. 1. Correlation between Snijders and Nicolaides biometry and Stirnemann et al. formula

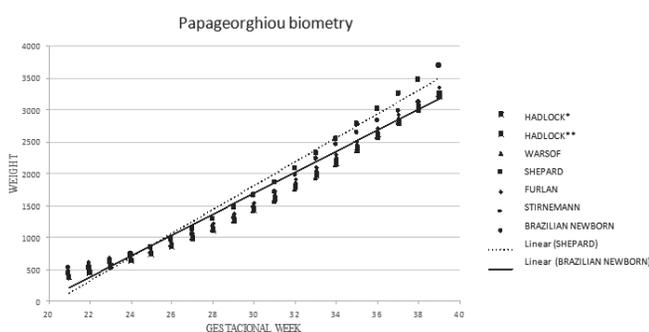


Fig. 2. Correlation between Papageorghiou et al. biometry and the Shepard et al. formula

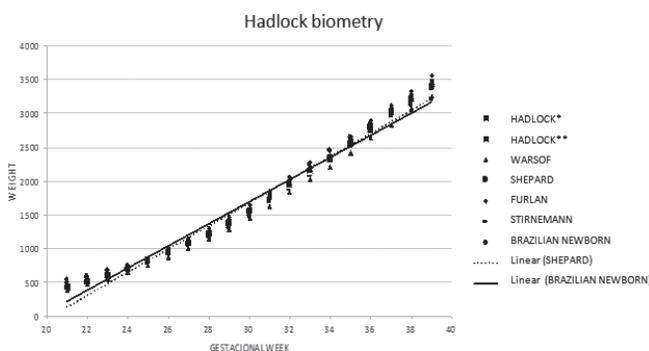


Fig. 3. Correlation between Hadlock et al. biometry and the Shepard et al. formula

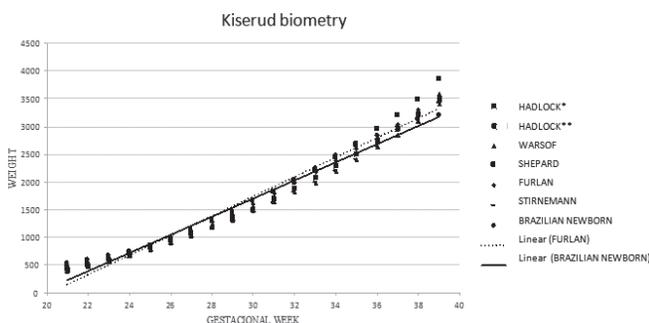


Fig. 4. Correlation between Kiserud et al. biometry and the Furlan et al. formula

between fetal weight and Lubchenco *et al.*⁽¹⁶⁾ table in order to correctly rank the newborns are possible.

The most commonly used formula for fetal estimated weight was developed by Hadlock *et al.*⁽⁵⁾, who published a study using BPD, HC, AC and FL for fetal estimated weight between 1984 and 1985. In this study, 361 pregnant women between 12 and 40 weeks were included with precise gestational age by last menstrual period, excluding patients with maternal disease that could interfere with fetal growth, as well as twin pregnancies. After this fetal biometry study, the authors created formulas for fetal estimated weight, using the developed biometric tables and matching the studied biometric parameters⁽¹⁰⁾. The Hadlock *et al.*⁽⁵⁾ study is widely used all over the world and it has more citations in the Medline database compared to recent studies by Furlan *et al.*⁽¹¹⁾, Stirnemann *et al.*⁽¹²⁾, Kiserud *et al.*⁽¹⁴⁾, and Papageorghiou *et al.*⁽¹⁵⁾.

It was observed that using biometric tables and fetal estimated weight formulas from different authors produced different percentiles for the same biometric measurement. The fetal weight was the same, but this value assumed different positions in percentile distribution. It was observed that fetal weight estimated from one author's formulas could be normal for a particular fetus, but above or below the normal percentile limits by another author. Thus, the use of fetal weight formulas and biometric tables constructed by different authors must be defined and used as the gold standard, so that comparisons can be made by different sonographers.

Pedreira *et al.*⁽⁷⁾ collected data from all Brazilian regions, reaching approximately 8 million birth weights. In this study, the authors also researched similar studies in other countries (Canada, United States, South Korea, Norway and Australia) in which birth weight curves were obtained by gestational age, and all had exclusion criteria such as maternal diseases and discrepant weights. Birth weight distribution in these countries showed little difference between 22 and 29 weeks, and this difference progressively increased until 42 weeks compared to Brazilian population.

Conclusions

In summary, using the Pedreira *et al.*⁽⁷⁾ table as gold standard in the Brazilian newborn weight population, the best correlation was found between Snijders and Nicolaides⁽¹³⁾ biometric table and Stirnemann *et al.*⁽¹²⁾ weight formula calculation.

Conflict of interest

Authors do not report any financial or personal connections with other persons or organizations, which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

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