

CLINICAL AND ULTRASONIC ESTIMATION OF FETAL WEIGHT

MASTER OF MEDICINE (OBSTETRICS AND GYNAECOLOGY)

DISSERTATION

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INTRODUCTION

Several clinical situations occur in obstetrics where it is useful to make an accurate assessment of fetal weight prior to delivery. A foreknowledge of the mass of the fetus can influence management in circumstances complicated by, for example, a previous caesarean section, a breech presentation, a compromised fetus of borderline viability and a diabetic pregnancy at term.

Researchers have attempted to estimate fetal weight by assaying oestriol (1), human placental lactogen (2), and pregnanediol (3). These parameters have been found to be of limited value because of the indirect measurement of fetal mass.

Since the introduction of ultrasound scanning techniques to obstetrics in the mid-1960's, it has become possible to visualise the fetus and to make direct measurements of fetal anatomy. By using ultrasound, workers have tried to predict fetal weight by measuring fetal heart volume (4), hourly urine production (5), trunk diameter (6), circumference (7) and placental volume (8).

At present various combinations of head circumference (HC), biparietal diameter (BPD), femur length (FL), and abdominal circumference (AC) are the most commonly used measurements which, when used in different formulas and read off tables estimate fetal weight.

Recently the gestational age (GA) has been incorporated into formulas specifically applied to small for gestational age (SGA), appropriate for gestational age (AGA), and large for gestational age (LGA) fetuses (9) (10). A sonographic estimation of fetal weight based on a model of fetal volume has also been developed (11).

It was generally believed that with the refining of ultrasonic estimation of fetal weight an accurate assessment of fetal mass could, at last, be made. Some investigators believe that the ultrasound estimation of fetal mass is more accurate than clinical assessment (12). In contrast other workers have shown that the accuracy of clinical examination is comparable to ultrasound determination in estimating fetal weight (13) (14).

TABLE 1

CLINICAL ESTIMATION OF FETAL WEIGHT
AS REPORTED BY SEVERAL INVESTIGATORS

AUTHOR	ACCURACY
Watson(13)	7.9% mean error
Insler(15)	Within 10% in 69% of estimations
Watson(16)	7.7% mean error
Loeffler (14)	Within 450g in 80% of estimations
Ong(17)	Within 450g in 82.5% of estimations

Many equations relating ultrasonic parameters to fetal weight have been developed. Most are polynomial or exponential functions utilising combinations of HC, BPD, AC, FL, and GA. Initially formulas incorporated BPD and AC measurements (12) (19). Use of the HC measurement was found to eliminate errors related to differences in the BPD attributed to normal variations in head shape (eg dolichocephaly or brachycephaly). Since femur length is an indirect measurement of fetal crown-heel length (21) it was considered an important contributor to calculating fetal weight. Thus the substitution of HC for BPD and the addition of femur length improved the accuracy of weight estimation and lowered the 2SD variation from 20.2% to 14.8% (20).

The mean error of ultrasound varies not only between formulas but also with each formula when used in different weight categories (18). For example, a particular formula may consistently overestimate small babies while underestimating larger babies. Combs (11) reduced the variability associated with changes in fetal weight by using a sonographic estimation based on a model of fetal volume.

To derive maximum accuracy in all fetal weight categories it may be necessary to examine the accuracy of different formulas within subgroups of fetal weight. It has been suggested that anthropological variations and subtle differences in imaging and measurement techniques may alter the accuracy of a formula for a particular population group (22) (23). Therefore, the exact formula(s) to be used for greatest accuracy may

population, measurement techniques and imaging technology available.

The current study was undertaken to determine the accuracy of clinical versus ultrasonic estimation of fetal weight across the range of fetal weights. This aspect has not been previously addressed. Another reason was to compare various formulas and combinations of formulas, to determine which fetal measurements are most appropriate for each weight category. Finally, the study aimed to propose which formulas to use in each weight category when scanning the Groote Schuur and New Somerset hospital antenatal populations.

MATERIALS AND METHODS

158 Women were evaluated between July 1990 and September 1993 at Groote Schuur and New Somerset hospitals. Being tertiary referral centres the study population comprised only high risk patients. The risk factors included medical, obstetric or both complications. Patients recruited had viable fetuses and were committed to deliver within 72 hours either by induction of labour or by caesarean section. All women had intact membranes, singleton pregnancies and longitudinal fetal lies. There were 8 breech and 144 cephalic presentations.

There were three ultrasonologists and two clinicians involved in the study. Each sonologist had several years of full-time obstetric ultrasound experience. The clinicians were obstetric registrars with three months of "focused practice" at estimating fetal weight. The great majority of clinical estimations were made by the first author.

Each patient was examined by a clinician and an ultrasonologist, the estimates being made independently and without foreknowledge of the other's assessment. All pertinent information regarding maternal height, weight and previous medical or obstetric history (including that of the current pregnancy) was made available to the examiners. The clinical estimation was made following routine abdominal palpation.

Ten commonly used equations utilising combinations of BPD, AC and FL were evaluated. In addition the weights from two of the more accurate formulas were averaged in an attempt to achieve greater accuracy.

TABLE 2

FETAL WEIGHT FORMULAS

AUTHOR	FORMULA
1 Shepard(19)	$\text{Log}_{10} \text{ Birth Wt.} = -1.7492 + 0.166(\text{BPD}) + 0.046(\text{AC}) - 2.646(\text{AC} \cdot \text{BPD}) / 1000$
2 Warsorf(12)	$\text{Log}_{10} \text{ Birth Wt} = -1.599 + 0.144(\text{BPD}) + 0.032(\text{AC}) - 0.111(\text{BPD} \cdot \text{BPD} \cdot \text{AC}) / 1000$
3 Warsorf(12)	$\text{Log}_{10} \text{ Birth Weight} = -1.8367 + 0.092(\text{AC}) - 0.019(\text{AC} \cdot \text{AC} \cdot \text{AC}) / 1000$
4 Warsorf(27)	$\text{Ln}(\text{EFW}) = [2.792 + 0.108(\text{FL}) + 0.0036(\text{AC} \cdot \text{AC}) - 0.0027(\text{FL} \cdot \text{AC})]$
5 Warsorf(27)	$\text{Ln}(\text{EFW}) = [4.6914 + 0.00151(\text{FL} \cdot \text{FL}) - 0.0000119(\text{FL} \cdot \text{FL} \cdot \text{FL})]$
6 Hadlock(22)	$\text{Log}_{10} \text{ Birth Weight} = 1.3598 + 0.051(\text{AC}) + 0.1844(\text{FL}) - 0.0037(\text{AC} \cdot \text{FL})$
7 Hadlock(22)	$\text{Log}_{10} \text{ Birth Weight} = 1.4787 - 0.003343(\text{AC} \cdot \text{FL}) + 0.001837(\text{BPD} \cdot \text{BPD}) + 0.0458(\text{AC}) + 0.158(\text{FL})$
8 Thurnau(29)	$\text{Birth Weight} = 9.337(\text{BPD} \cdot \text{AC}) - 299.076$
9 Campbell(28)	$\text{Log}(e) \text{ Birth Weight} = 0.282(\text{AC}) - 0.00331(\text{AC} \cdot \text{AC}) - 4.564$
10 Deter(30)	$\text{Log}_{10} \text{ Birth Weight} = 0.211(\text{BPD}) + 0.057(\text{AC}) - 0.00403(\text{BPD} \cdot \text{AC}) - 2.104$
11 Average 6 and 7	
12 Average 1 and 6	
13 Clinical estimation	

BPD measurements were made by the "outer to inner technique" taken at the level of the septum cavum pellucidum and thalamus. FL measurements were made using the diaphysis of the femur. Wherever possible the femur was measured horizontally in relation to the ultrasound probe.

The AC measurements were taken in a transverse section of the abdomen of the fetus where the following structures were visible: spine, cross section of the descending aorta, stomach and the bifurcation of the intrahepatic portion of the umbilical vein. Measurements were taken with particular caution to avoid compression of the abdomen. The fetal abdominal circumference was traced using the maximum perimeter.

For sonographic measurements the following ultrasound machines were used:
1: Siemens sonoline SL2 with a 3.5 MHz mechanical sector probe.
2: Aloka SSA - 650 with a 3.5 MHz curvilinear probe.

The distribution of the percentage error data was tested for normality using the Shapiro-Wilk test. The (signed) mean percentage error for the different equations was calculated in the following way: $[\text{estimated fetal weight} - \text{birth weight}/\text{birth weight}] \times 100$. The standard deviation and 95% confidence interval of the mean percentage error was calculated, the latter using the t-distribution. Pearson's correlation analysis was done with birth weight on estimated fetal weight. The coefficient of determination (R^2) was calculated for each of the formulas. Statistics were done on both crude and stratified data.

Stratification was done using actual (and not calculated) birth weight: less than 1500g, 1500 - 2500g, 2500-3500g and greater than 3500g. There were 2 main reasons for choosing the stratifications in the above fashion namely, clinical application and sample size. Clinical decisions regarding the mode of delivery are often made when the fetus is estimated to weigh either 1000g (or less) and 4000g (or more). The groups were therefore chosen to have these two weights as the midpoint of the groups, and not at the end of the range. The percentage error in predicted weight could therefore be observed around about these midpoints and the best formula chosen. The second reason for this stratification was that the small sample size prevented further division into smaller units, say for example into 500g groups. Larger groups (bigger sample) with better statistical properties were therefore chosen.

RESULTS

The fetal weight formulas are listed in Table 2. The (signed) mean percentage error of weight as well as the standard deviation of this error and the 95% confidence intervals are shown in FIGURE 1(a)-(e). The coefficient of determination values of the estimated weights against the true weights are also shown in the same figure.

FIGURE 1a (n = 158)

Signed percentage error (all weight groups)

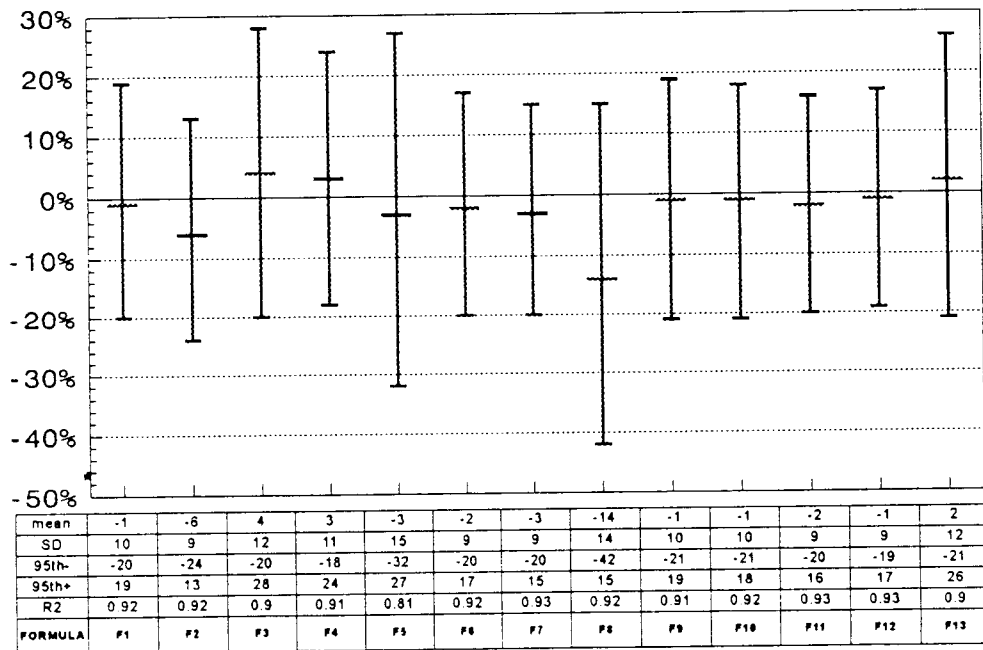


FIGURE 1b (n = 28)

Signed percentage error (<1500g)

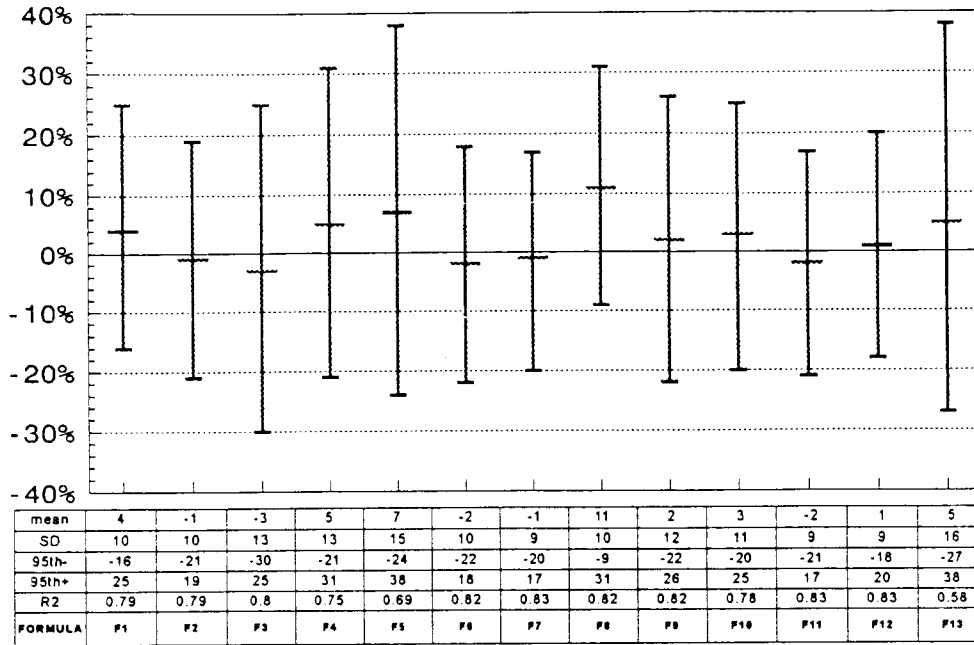


FIGURE 1c (n = 22)

Signed percentage error (1500-2500g)

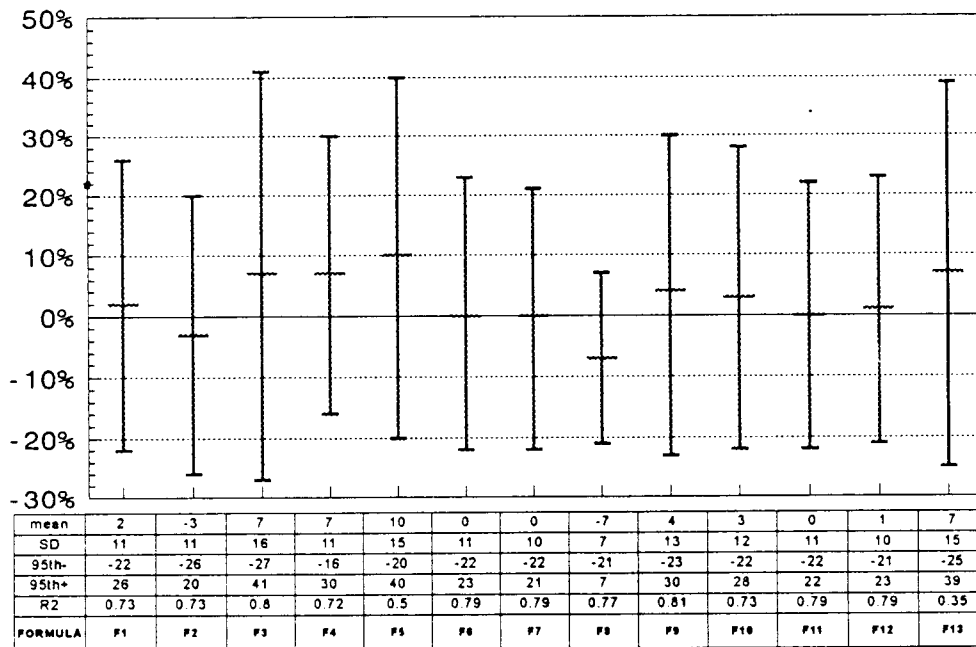


FIGURE Id (n= 73)

Signed percentage error (2500-3500g)

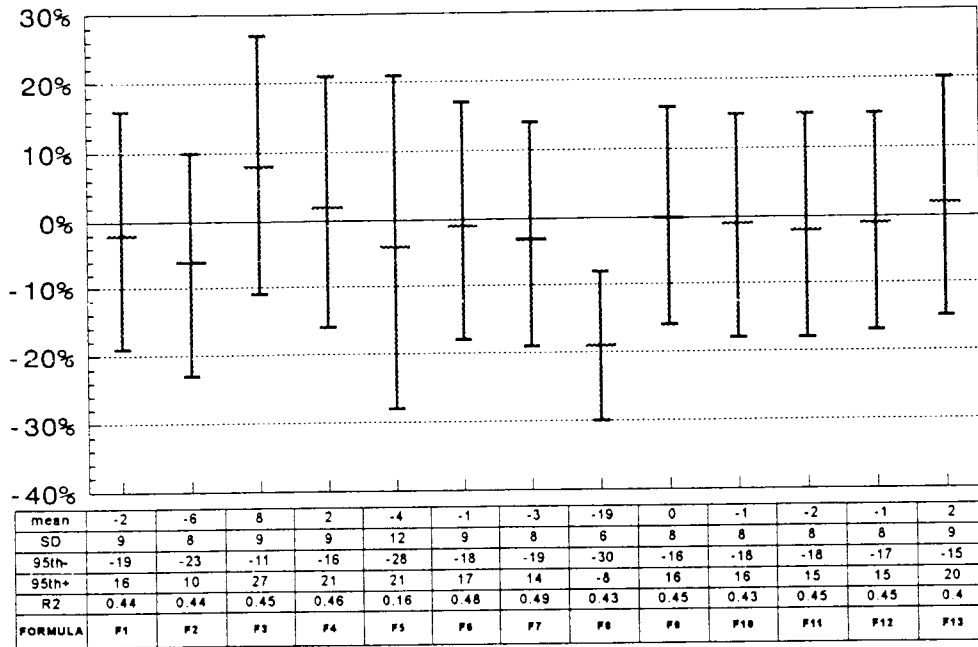
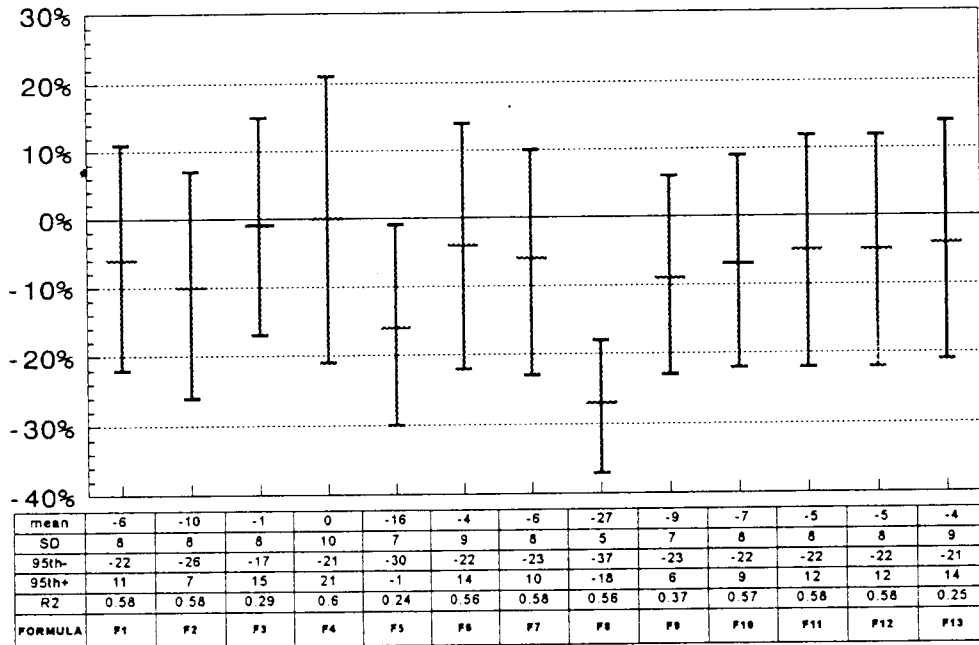


FIGURE Ie (n = 35)

Signed percentage error (>3500g)



If we consider the mean error, the 95% confidence intervals and the coefficient of determination, the following facts become apparent :

- 1.) The mean percentage error of clinical estimation of fetal weight is comparable in all fetal weight groups to ultrasound measurements using the majority of formulas. However, the 95% confidence intervals are greater than most ultrasound formulas in babies <2500g.
- 2.) In the weight category <1500g, formulas 7, 11, and 12 were the most accurate (FIGURE 1(b)).
- 3.) In the 1500 - 2500g category the findings were the same as above. Formula 6 was also accurate in this weight category (FIGURE 1(c)).
It is significant that apart from formula 6 the above mentioned formulas incorporate all three fetal parameters, i.e. BPD, FL, and AC.
- 4.) In the 2500 - 3500g category formulas 9, 10, and 12 were most accurate (FIGURE 1(d)).
- 5.) In fetuses of >3500g, formula 3, which uses AC only, was most accurate. Next best were formulas 4 and 6 (FIGURE 1(e)). In fetuses >2500g, BPD was not a parameter used in the equations of the more accurate formulas.
- 6.) Formula 8 was consistently the least accurate formula in terms of mean percentage error. Paradoxically, it was this formula that showed the narrowest 95% confidence interval of its mean.
- 7.) The variability of percentage error with increasing fetal weight showed most formulas to underestimate larger fetuses. Formula 4, however, did not reflect this bias and showed a zero mean percent error in fetuses >3500g (FIGURE 1(e)).
- 8.) Previous studies showed a tendency to consistently overestimate the mass of small babies, but this was not the case in the present study (FIGURE 1(a),(b)).

DISCUSSION

Several interesting findings have arisen in this study. We have shown for the first time that clinical estimation of fetal weight by a trained person is as accurate as ultrasonic estimation in babies > 2500g. In those fetuses < 2500g clinical estimation is less accurate in terms of the 95% confidence interval. The practical implication of this finding is that in a setting where an ultrasound machine is not immediately at hand, a trained person may be usefully employed in those clinical situations where an accurate assessment of fetal weight is essential. In babies < 2500g, transferring the patient to a centre that has ultrasound (and more importantly neonatal facilities) is advisable. Attempts have been made in the past to estimate birth weight by external uterine measurements and applying these to formulae (24) (25) (26). This did not improve clinical accuracy.

The findings of our sonographic weight estimations show both similarities and differences to other studies. The variability of percentage error with increasing weight was generally consistent with other studies (18) - there was the tendency to consistently underestimate larger fetuses (FIGURE 1(e)). Robson (9) (using several formulas) showed a tendency to overestimate lower birth weight fetuses, though this was not evident with many formulas used in our study (FIGURE 1(b)).

Of note is the small standard deviation of the percentage error in our study. It was considerably less than in the study of Ott (18) which also considered formulas 1 and 2.

Formulas which utilise more than two parameters are shown in this study to be best at estimating weight in babies of less than 2500g. As pregnancy approaches term, head growth slows and BPD carries less value as a parameter in estimating weight. It should therefore not be used as a parameter in calculating weight in babies over 3500g. This also applies to babies between 2500g and 3500g since the two most accurate formulas in this group excluded BPD from their equations. These findings are not reported elsewhere in the literature.

In the Groote Schuur and New Somerset Hospital antenatal populations the best formulas to use in babies under 1500g and between 1500g and 2500g are formulas 7, 11, and 12. Robson (9) also found in a study which looked specifically at SGA fetuses that Hadlock's formula (formula 7) had the lowest error.

In the weight group 2500 - 3500g formulas 9, 10, or 12 should be used while in babies over 3500g formulas 3, 4, or 6 will yield best results in our patient population.

An interesting observation is that in our patient population formula 8 has the potential for being the most accurate formula in all babies over 1500g. This deduction is based on the fact that it has by far the narrowest 95% confidence interval (FIGURE 1 (c), (d), (e)). To improve accuracy a correction factor to the existing formula is required to correct the poor mean error.

In the 1500g "cusp area" (the fetal mass closely adjacent to the weight group limit) the most accurate formulas on either side of this weight are identical (except for formula 6 which can also be used in babies 1500g-2500g). There may be a marginal accuracy difference by comparing formulas above and below the 2500g and 3500g "cusp areas". The gain, if it exists, is likely to be marginal in view of the small differences in mean error and standard deviation between the best formulas used on either side of these limites (Figures 1c-e).

What is considered relevant, however, is the fact that important clinical decision making occurs at weights of 1000g, 1500g and 3800-4000g. The formulas to use regarding the first two weights have been discussed and are identical. The last mentioned weight (3800-4000g) is beyond the "cusp region" and therefore the best formulas to use in this circumstance are those described for babies > 3500g.

Of importance in our study is the fact that the patient population was of high risk and included a large number of hypertensive and diabetic women. In the smaller fetuses it is likely, therefore, that many were growth retarded with a falloff in AC, while having spared head growth and (to a lesser extent) spared femur growth. Diabetics on the other hand are known to develop disproportionate abdominal growth relative to other parameters in late pregnancy. The physical parameters of these high risk babies are, therefore, not the same as those of "normally grown" small and large fetuses. These facts are important since they are likely to make conclusions regarding specific formulas relevant to our particular patient population only.

The search for the best formula to serve all weight groups of babies will continue. Combs (11) made use of sonographic estimation of fetal weight based on a model of

fetal volume and found it provided accurate estimates of weight across a broad range . This model used HC as one of its measurements, but was not assessed in our study.

Any formula which is accurate across the whole range of fetal weights will need to exclude BPD as a parameter due to its wide 95% confidence interval in large babies. This is likely to be at the expense of reduced accuracy in small fetuses. Since head growth slows in term fetuses, HC is unlikely to prove substantially better than BPD in large, term babies.

To achieve maximum accuracy the most appropriate formula will probably need adjustment depending on the weight group of the fetus. Also influencing the choice of a formula will be the population group. Jordaan (23) noted that anthropological differences may limit the use of his regression model to South African populations.

Robson (9) used "targeted formulas" to prospectively estimate fetal weight in SGA fetuses and compare them with five previously reported formulas. He made use of linear, quadratic, and cubic models all of which incorporated GA in their formulas. He failed to find a formula which estimated weight significantly more accurately than any other and felt the choice of formula depends mainly on the measurements available and the ease of use. His linear formula using GA, AC and FL showed estimation errors which did not vary with birth weight - a problem inherent in most general formulas. However, his study looked at SGA fetuses only and did not include babies over 3500g.

Sabbagha (10) reported formulas targeted to SGA, AGA and LGA fetuses. Fetuses were classified into three groups on the basis of the growth percentile rank of the abdominal circumference (>90%, >5% and <90%). Regression analyses were performed to generate three formulas for estimating fetal weight on the basis of GA, HC, AC and FL. Using these he showed no significant systematic error and reduced random error associated with birth weight estimation.

A disadvantage of the targeted formulas thus far described is that they require an accurate knowledge of GA. In the population we studied the majority of patients are either unsure of dates or their booking visits are too late for accurate ultrasonic gestational aging. Hence any targeted formulas in a population such as ours will need to exclude GA as a parameter.

CONCLUSION

Clinical estimation of fetal weight is an acquired skill which can be developed to achieve the same accuracy as ultrasonic estimation in fetuses >2500g. In smaller fetuses, the 95% confidence interval is considerably wider than most commonly used formulas. When BPD, AC and FL are the parameters measured ultrasonic formulas or combinations thereof which utilise all three parameters are most accurate in estimating babies under 2500g. In babies over 3500g BPD becomes misleading in estimating weight and formulas which include this parameter should not be used. This is to a lesser extent also applicable to babies between 2500 - 3500g.

There is currently no single formula which is accurate across the whole range of fetal weights. When GA can be accurately determined targeted formulas for SGA, AGA and LGA are likely to be most accurate.

The exact formula(s) to use may vary between centres depending on differences in measurement techniques, the imaging technology available, anthropological variations, and obstetric and medical risk differences between populations.

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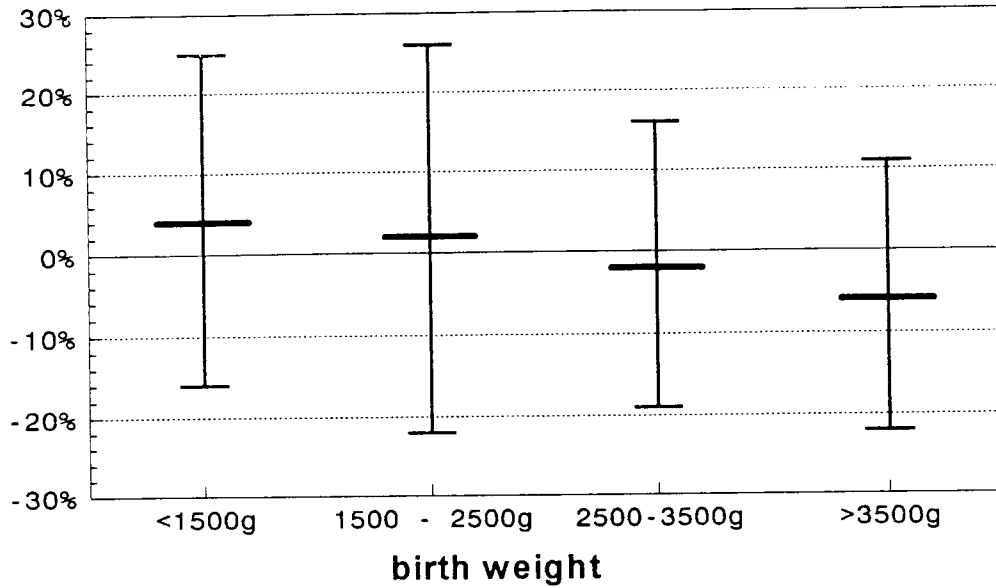
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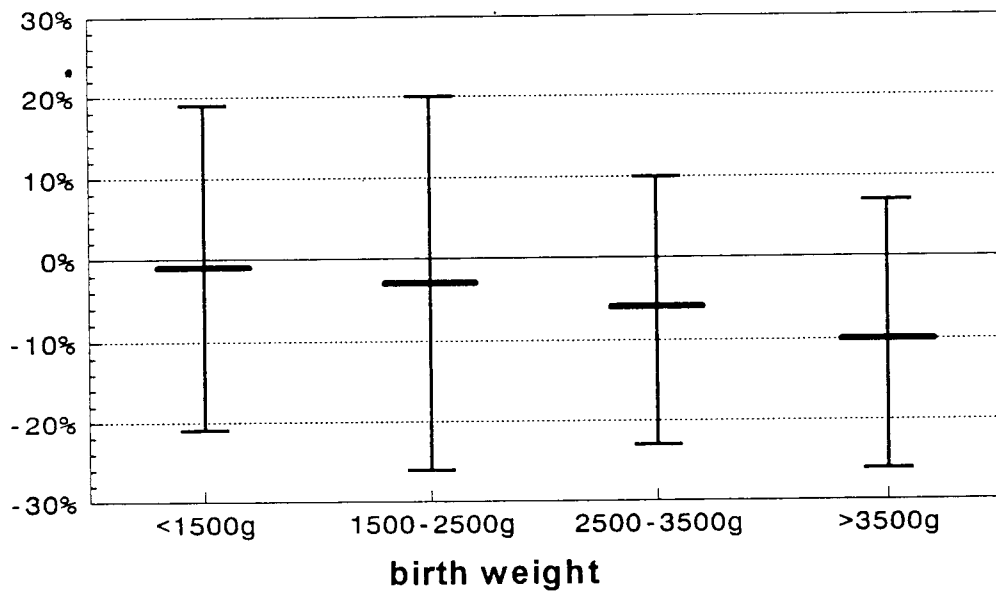
APPENDIX

(SIGNED) MEAN PERCENTAGE ERROR

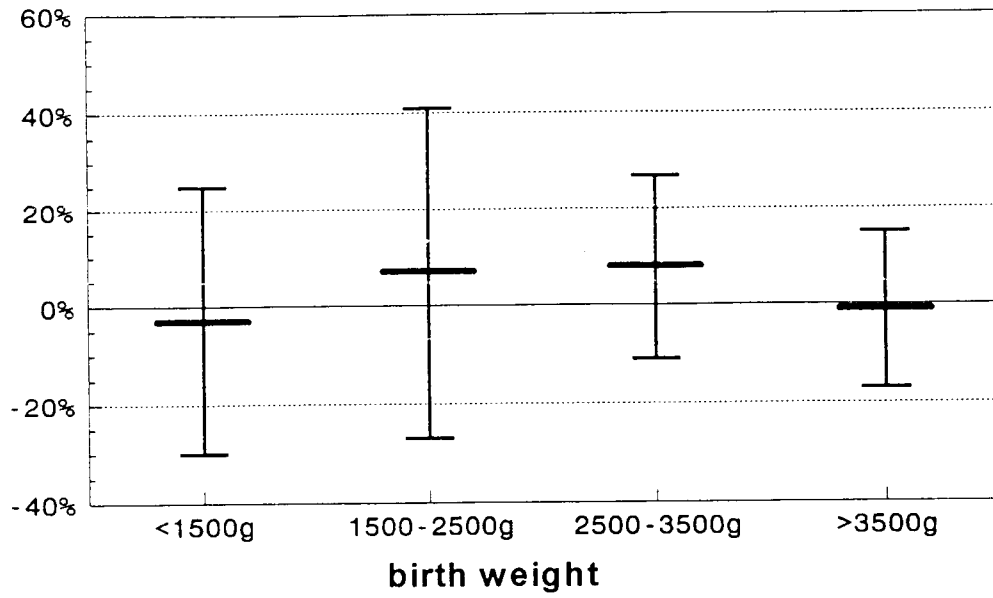
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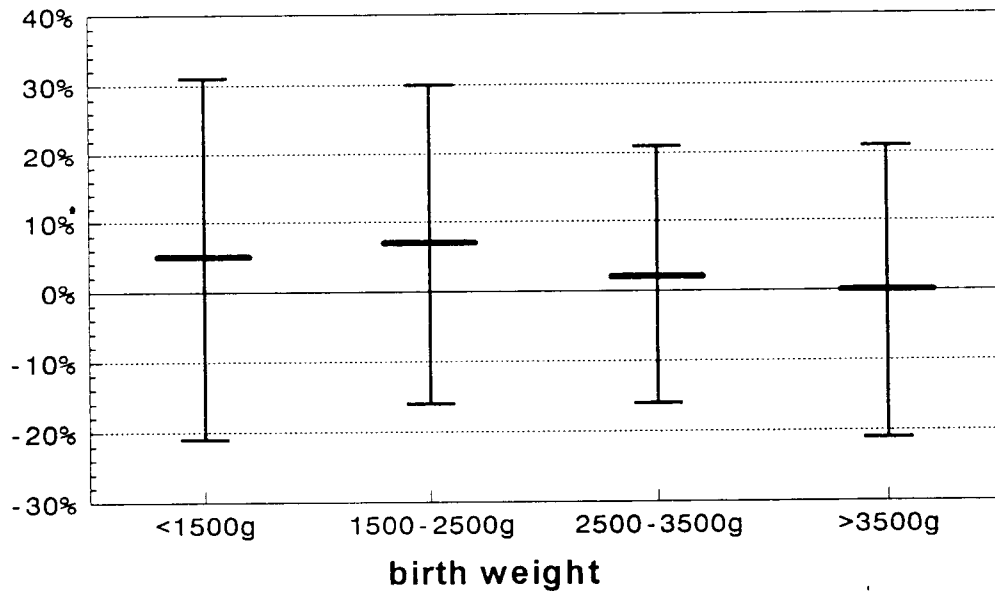
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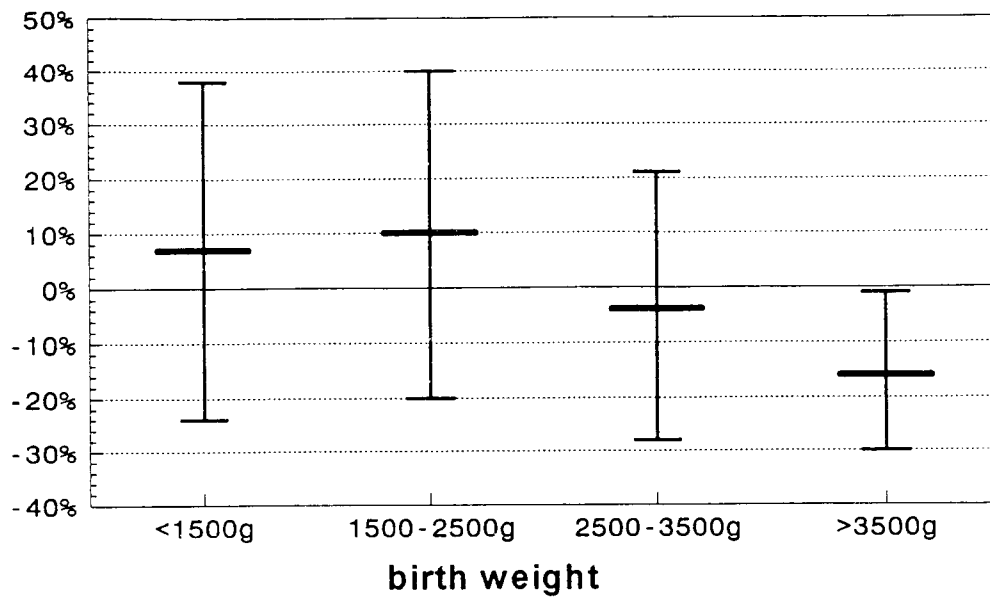
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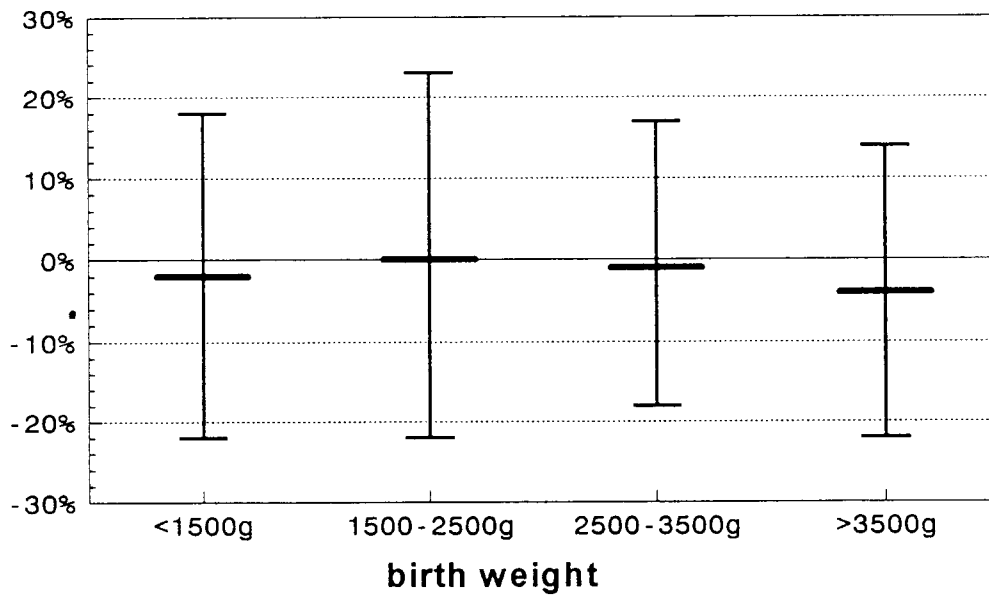
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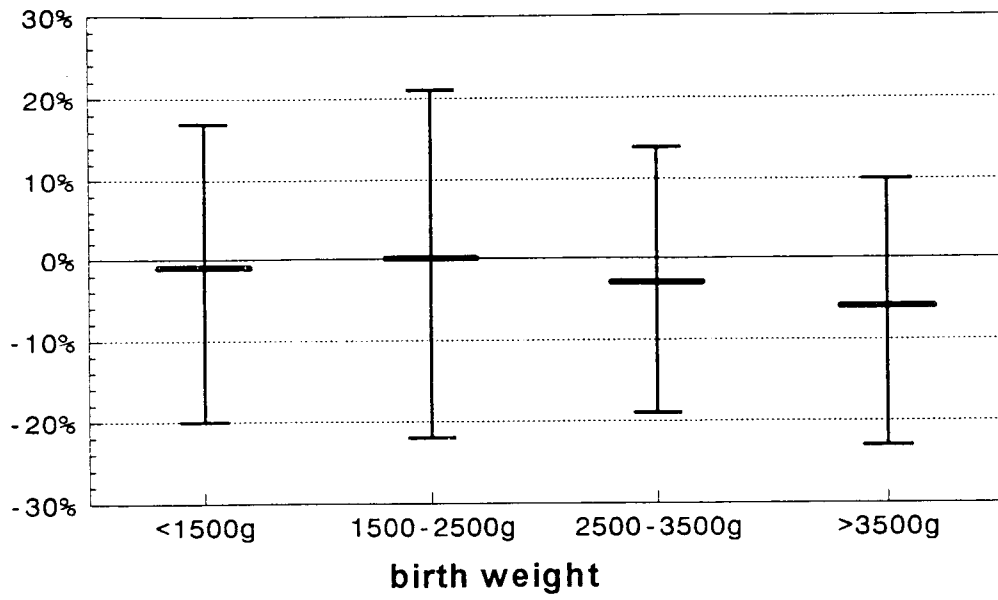
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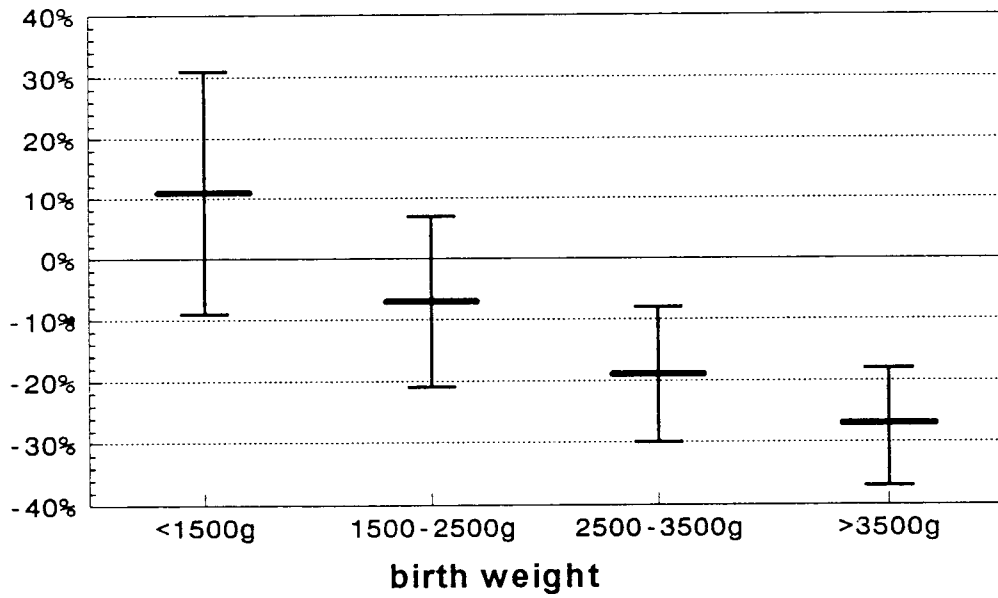
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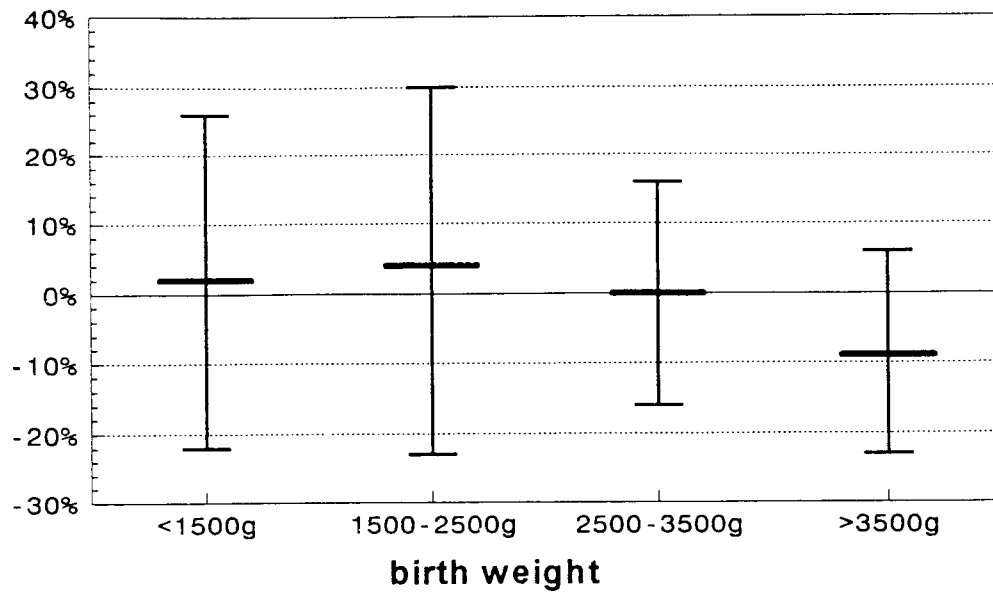
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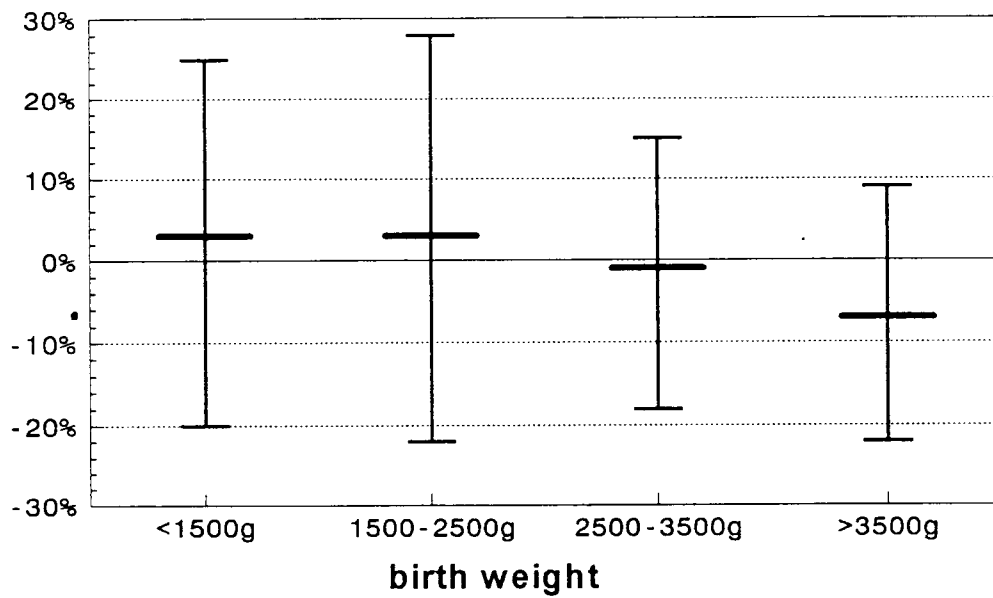
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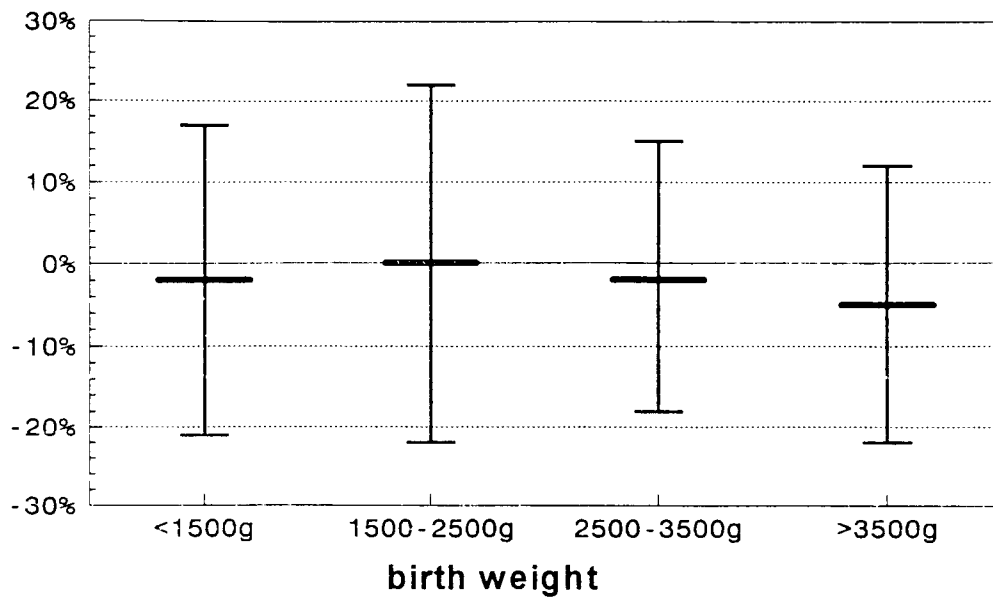
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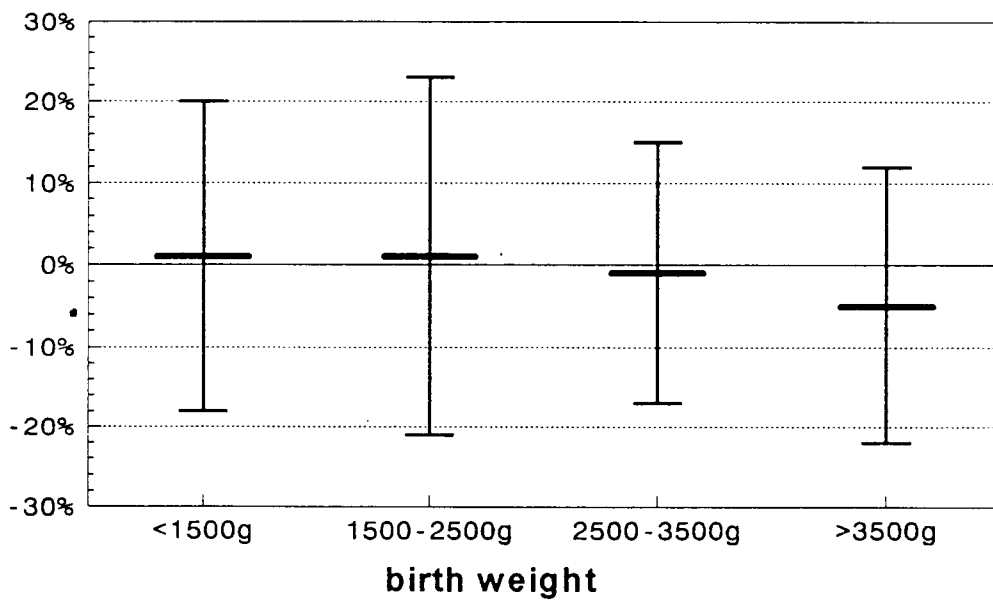
formula 10



formula 11



formula 12



Clinical

