ULTRASONOGRAPHIC FOETAL AGE ASSESSMENT

VERSUS

MENSTRUAL AGE IN THE SECOND AND THIRD TRIMESTER

A Study conducted at Kenyatta National Hospital, Nairobi

1st July, 1992 - 31st March, 1993.

A Dissertation submitted in part fulfillment for the Degree of Master of Medicine (Diagnostic Radiology), University of Nairobi.

May 1993

Dr. Wanga O.J. Henry M.B.CH.B (Nairobi)

DECLARATION

Candidate:

This dissertation is my original work and has not been presented for a degree in any other University.

Signed: . . . . . .

DR. WANGA O.J. HENRY M.B.CH.B(NBI)

Supervisors:

This dissertation has been submitted for examination with our approval as University Supervisors.

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DEDICATION

To my late Nephew Shem,

On 15th June, 1990, 2.00p.m. aged nine at Kenyatta National hospital you took your last breath after laboring under complicated Rheumatic Heart Disease sitting up days and nights for six months. At school as well as in ward 8, you were uniquely attentive. What you wrote and drew in pictures says alot about your interrupted ambitions. I felt robbed but prayers assure me your are safe in heaven.

To you Francis, my late father-in-law,

In death you are remembered for generosity, humor, kind counsel, and tremendous inspirational advice that converted the feeble strong.

The tragic hands of murderers drove a bullet into your heart in your house on the fateful night of 28th September, 1989 - 9.30p.m.! I felt wounded.

Oh God permit me to tend the sick and wounded ever more closely to realise the richness of your purpose.

CONTENTS

SUMMARY

The author presents three hundred and ninety-five women who underwent obstetric ultrasonography between July 1992 and March 1993. The aim was to assess the accurate relationship between known menstrual age visa vis femoral length, biparietal diameter, head circumference and abdominal circumference. It was done for gestation age fourteen to forty-two weeks.

Out of the 395 clients all attending ante-natal clinic at Kenyatta National Hospital, 296 were sure of their normal last menstrual period. These numbers were assessed and found statistically viable.

Ultrasonography machines used were:-

1. Phillips Orion Model using 4MHz linear transducer at X-Ray Department of Kenyatta National Hospital.
2. Aloka SSD 650 using 3.5MHz linear transducer at Kenya Medical Research Institute, Headquarters, Nairobi (Clinical Department).

No significant results differences were observed in patients examined at the two centres.

Biparietal diameter, femoral length, head and abdominal circumferences were worked out and compared with known menstrual ages. Outliers removed, there was good correlation between known menstrual age and ultrasound measurements.

Linear cubic regression analysis proved superior to linear quadratic. Using the formula obtained from the computer statistical package i.e.

bpdcp = a+(bxlmp) + (cxlmp3) where bpd is biparietal diameter, a,b&c are constants. Bpd is substituted for by femoral length (FL), head circumference (HC) and abdominal circumference to obtain regression value for each studied parameter.

Goodness of fit, (R^2) was as follows:-

Biparietal diameter	=	80.381%
Femoral length	=	81.366%
Head circumference	=	84.999%
Abdominal circumference	=	79.578%

Results obtained by ultrasonography compared favourably with those of Campbell S. et al, Hadlock et al and Sabbagha et al, as well as those done locally by Drs. Rogo K., Dhadialla H. and Qureshi Z.P. Importance of obstetric ultrasonography is underlined.

Controlled and funded multi-disciplinary study recommendations are presented. These come in the discussion section. Conclusions which are made amplify clinical applications that arise following accurate cross sectional studies.

Besides limitations that are correctable, it would require collaborative work between sonologists, obstetricians, technicians, administrators and statisticians.

INTRODUCTION

Historical background.

Ultrasound is a form of mechanical energy whose frequency is far beyond the upper limit of human hearing range of 20 (twenty) kilohertz.

In 1912 the first ultrasound machine was designed by a French engineer named Paul Lengeurin. He stated that transducers are composed of PIEZO-ELECTRIC CRYSTALS in which electrical energy is transformed into mechanical. Ultrasound waves are mechanical vibrations transmitted as longitudinal waves requiring a medium. In bone they are nearly completely absorbed creating an acoustic shadow.

However, ultrasound waves are propagated through soft tissues at a velocity of one thousand, five hundred and forty meters per second (1540 m/sec).

In 1919 the Titanic ship was sunk in battle. Initial uses of ultrasonography included locating of the Titanic. Hence the terminology SONAR meaning sound navigation and ranging was coined. Its use in metallurgy to locate flaws began in 1930s. By the late 1950's it gained prominence in medical work - Donald, Ian et al (1).

Our interest in ultrasonography is for information gathered at the same tissue level. Liquids transmit almost all ultrasound waves and behave as acoustic windows through which subjacent organs are probed.

99.9% of ultrasound is reflected at soft tissue - air interphase, necessitating an oil or gel coupling medium. At frequencies range 2.5MHz to 4MHz all obstetric work is done perfectly using linear and sector transducers.

In this study, a B-mode (Real time dynamic scanning) linear transducer was used; with M-mode for cardiac activity demonstration. Pulse-echo technique has the sole purpose to transmit a short ultrasonic pulse and detect all the returning echoes using the same transducer. Time gain compensation for distant echoes can be adjusted. Quality: Guaranteed by multi-element transducer arrays with $\geq$ 60 frame rates per second.

Safety: There is near complete safety as assured by the 1984 National Institute of Health of the U.S.A. seminars. No significant degree of heating or cavitation occur at diagnostic frequency range 2-8MHz. (Ref: Diagnostic Ultrasound imaging in pregnancy) (2).

The necessity to beat the deadline for my study made us supplement the use of Phillips Orion Kenyatta National Hospital Ultrasound Machine with the SSD 650 ALOKA - KEMRI Ultrasound Machine.

Preliminary sonography of three pregnant mothers in second trimester using the two machines above produced comparable results. This validates my study which also reveals that on Aloka machine, film image is sharper and more distinct than Phillips. Both are of high quality.

For the three hundred and ninety-five patients, the machines described gave excellent measurements. These were biparietal diameter, head circumference, abdominal circumference and femoral length.

I am motivated by the fact that in combination, the four parameters have not been studied at the Kenyatta National Hospital.

In future this will broaden the base of local normal sonographic standards. For example when the foetal skull is in unfavourable position, the sonographer should refer to femoral length. This need to be familiar to the sonologist and sonographer.

However, in a short period such as I have, the funds available and limited interdepartmental experience, my study will be restricted to the 395 patients.

LITERATURE REVIEW

SECOND AND THIRD TRIMESTER FETAL AGE AND WEIGHT ASSESSMENT

Campbell S. et al (3) in 1985 took 4527 consecutive women scanned by technicians at King's College Hospital and the results were analysed.

His conclusion was that between 12 and 18 weeks' gestation, biparietal diameter measurements were accurate. In this group, 2410 pregnancies datable by menstrual history met the delivery criteria. Of these 1317 had optimal menstrual histories, while 84.7% delivered within ±two weeks of their clinical estimated date of confinement.

Among those with suspect menstrual history, observation showed that they performed poorly. Menstrual history prediction by biparietal diameter, 89.4% delivered within ±2 weeks of the date predicted ($P<0.001$).

In his study, Campbell S. et al found that approximately 19.4% of the total group of women were unsure of their menstrual age.

Conclusions drawn emphasized that the cost of ultrasonography and hospital centered institutions biased selection and results. Those who lived near such institutions and could afford benefitted from services of obstetric ultrasonography.

Frank P. Hadlock et al in 1987 (4) examined 300 indigent black (38%) and Hispanic (62%) patients in a county Hospital in the Houston area of Texas State, USA.

It was felt that although multiple fetal measurements to predict menstrual age is accepted, more studies were necessary.

Regression equations drawn applied well in other areas with different socio-economic and racial characteristics. This study concluded that each laboratory should develop its own equations using multiple parameters.

Earlier in 1961, Donald and Brown - Campbell S. 1968 (5) described an ultrasonic technique for determining fetal biparietal diameter. This was improved upon by Campbell in 1968 when he combined use of undimensional A scan and plan position indication or B scan. It permitted measurement of fetal biparietal diameter between 20-30 weeks for the first time then.

Campbell (1968) measured transverse diameter between both parietal eminences perpendicular to the midline echo. Later in May 1982, Hadlock, P.F. et al(6) using a 3.5MHz linear transducer did serial transaxial scans parallel to canthomeatal line. Level two, defined as including anechoic midline, originally described by Campbell and Thomas, it was thought represented cavum septum pellucidum.

Justification of the line described above by Campbell and Thomas, in 1977, was made by Hadlock et al. In May 1982 he emphasised:-

(1) Production of the plane for correct measurement.

(2) Specific anatomic landmarks for reference.

(3) Comparison of this plane with others using varying data. Results from this study and that of Campbell/Thomas agree.

(4) Measurement along the plane of head circumference on basis of maximum occipito-frontal diameter.

In 1983, Rogo(7) at Kenyatta National Hospital found out that foetal biparietal diameters compared with those done in affluent countries. Growth peaks were two: 20-30 weeks and 30-40 weeks. In 1983, Osefo(12) and others found similar results among women in Nigeria.

Campbell and another presentation by Hadlock stated that there is a progressive increase in the mean BPD up to forty weeks.

Sabbagha E. Rudy et al in 1974(8) said that the straight line fit for the regression of menstrual age (x) on BPD (y) where $y \geq 7.0$cm and n=158 coordinate points, is X = 7.151+2.8574.

R2 = .825 - with confidence

intervals: X = 1.6 weeks.

The purpose of his study was to define the accuracy of the sonar biparietal diameter (BPD) as a predictor of gestational age.

Dhadialla in 1986(9) at Aga Khan Hospital did a prospective study to show biparietal nomogram representative of middle class African and Asian patients attending antenatal clinic. For about 340 patients he took 1100 measurements at 4-weekly intervals of both biparietal diameter and fetal abdominal circumference. He was able to say when best B.P.D. measurements predict menstrual age.

Three years later at Kenyatta National Hospital, Dr. Z.P. Qureshi (10) did a similar study emphasising relationship between femoral length and biparietal diameter

for fetal age dating. Out of about 500 foetuses she concluded that BPD is a better predictor compared to femur length.

Other studies on Biparietal Diameter measurements have been done by Sabbagha et al (1974), Osefo et al (1983) and both agree on plane of scanning. Osefo maintains that in Africans, foetuses have a smaller biparietal diameter in comparison to Caribbean and American study results.

Doubilet M. Peter et al (13) carried out research on a topic entitled, 'Improved Prediction of Gestational Age from Foetal Head measurements'. The study consisted of 4051 consecutive obstetric patients for; 1. Crown rump length, 2. fetal biparietal diameter, and 3. occipito-frontal diameter.

He stated area corrected biparietal diameter. This is the biparietal diameter of the standard shaped head with the same cross sectional area as that of the fetal head examined.

Assumptions in this study were:-

1. Cephalic Index changes with advancing fetal age.
2. To give a threshold Cephalic Index that would maximise sensitivity for detection of misleading BPD due to altered head shape.

$$\text{Cephalic Index} = \frac{\text{Biparietal Diameter}}{\text{Occipito-frontal Diameter}} \times 100\%$$

Inferences: Biparietal diameter measurements are valid if they fall within the 95% confidence interval of the Washington University reference curve, and those falling

outside invalid.

Kurtz A.B. et al 1980 (14) came up with graphs and tables for conversion of biparietal diameter into menstrual age in weeks to which wide reference is now made.

FETAL HEAD CIRCUMFERENCE

In 1982 Hadlock et al (15) studied four hundred consecutive patients chosen for analysis based on:-

1. Certainty of menstrual age.
2. Clinical evaluation.
3. Fetal head in occipito-transverse position so that anatomic planes could be easily recognised.
4. Free of serious maternal illness.
5. Single foetus.

The results of this study were analysed by both linear quadratic (r=98.3%) and linear cubic (98.3%) functions which could be considered the optimal model. He showed that the graph of head circumference versus menstrual age is non-linear.

Head circumference is a more useful index of fetal maturity in which variations of fetal head shape (e.g. Dolichocephaly, brachycephaly) adversely affect the accuracy of biparietal diameter.

O'brien D.G. et al 1981 (16) measured foetal femur length by real-time ultrasonography in second trimester. Only calcified portions of the bone were measured.

Results were assessed for reproducibility and reliability of ultrasound for prediction of foetal age.

Hadlock et al (1982) (18), the following year, studied sonographically 338 middle class white women. Fetal femur was found to lie almost in all cases in a horizontal position. A focussed transducer ADR - Tempe, AZ was aligned along the longest axis of the femur. The relationship between femur length and menstrual age (r^2 = 96.6%) was described by linear and quadratic functions; linear quadratic function (r^2 = 97.7%) was better.

ABDOMINAL CIRCUMFERENCE

Work on foetal abdominal circumference for gestation age and fetal weight assessment has been extensively studied. Stuart, Campbell and David Wilken in British Journal of Obstetrics in 1975 (44) explained the relationship between gestation age, foetal weight, and abdominal circumference. They sonographed mothers within forty-eight hours of intended delivery at different gestations in second and third trimester. Birth weight prediction varied with the size of the foetus such that foetal weight steadily rose in third trimester. If birth weights were transformed to log, e values the variations were approximately the same over the whole range of abdominal circumferences.

A second degree polynomial regression of the form $Y=a+bX+cX^2$ (where Y = birth weight and X = abdominal circumference) was fitted to the transformed data using appropriate compute programme.

Hadlock et al 1982 (19) recommended measurement of abdominal circumference through a dotted line round the abdominal wall at the point where umbilical vein enters the lines forming the portal vein, and stomach.

Four hundred foetuses were looked at from gestation, 15 weeks till 41 weeks using a linear array real time ultrasound scanner - following specifically defined methodology.

Results showed that foetal abdominal circumference is a worse predictor of menstrual age than biparietal diameter. However, for gestation age between 36-42 weeks, foetal abdominal circumference is consistently useful.

Poll V. et al (1979) (20) described a simple and accurate method for estimating fetal weight from a single abdominal circumference. This was converted into a weight centile for maturity at the time of measurement so that the weight at delivery could be predicted.

Work by Rumack M.C. et al (1991) (21) in diagnostic ultrasound chapter 34 gives an up to date comprehensive method for estimating foetal weight. Various methods are given. In one a combination of biparietal diameter, femoral length and abdominal circumference is used. In another fetal femoral length is measured in combination with abdominal circumference. Employing linear cubic regression model, it was possible to draw graphs for foetal weight versus menstrual age.

MATERIALS AND METHODS

The purpose of this study is to analyse comparative and contrasting fetal growth parameters against menstrual age.

Most antenatal patients at the Obstetric Clinic at Kenyatta National Hospital, although a referral centre, were on history and physical examination found to be normal pregnant women. It is this group we targeted for a sample of three hundred and ninety-five. They were further reduced to approximately 280 who had complete data on menstrual age and deemed to have reliable information.

Important Historical Considerations

1. Family history free of:
   (a) Severe maternal illness such as diabetes mellitus, hydrops foetalis, hypertension in pregnancy or psychiatric illness.
2. Cessation of oral contraceptive usage three months prior to present pregnancy.
3. Non-depo provera users for at least six months as its prolonged use alters menstrual pattern.
4. No anaemic status, nor predisposing factors such as severe malnutrition or sickle cell disease status
5. Known non-smokers, Non-alcoholics.
6. Certainty of previous menstrual period.
7. Anticipated term delivery.

Sociodemographic data: Age, marital status, parity, foetal loss, and income/expenditure outcome variables are taken but will not be subjected to mathematical testing. This is because they were not adequately controlled for.

Patients were selected after obtaining verbal consent. This was sometimes influenced by convenience to them concerning time and to the sonographer depending on how busy the ultra sound machine was with routine hospital work. The youngest woman was 15 years old and the oldest 42. Most of the women were married, lived in the city centre and sub-urban areas.

They largely fall into low socio-income bracket, a small proportion would be said to be middle class, including a few professionals. This classification is based on estimates as most clients did not keep record of their income nor expenditure.

Ability to pay by each patient examined at Kenyatta National Hospital, Ultrasonography Department was essential. They were charged like other ordinary obstetric cases KShs.300. At KEMRI I negotiated for KShs.200 per patient examined and paid for those clients I studied using SSD 650 ALOKA.

Measurements

Biparietal Diameter

Taken in a transaxial plane, biparietal diameter (BPD) was measured at the widest portions of the skull. A leading edge to leading edge measurement was obtained from the first echo of the closer temporoparietal calvarial table to the first echo of the farther temporoparietal calvarial table.

It was taken across the plane of occipito-frontal diameter.

Head Circumference

The study consisted of three hundred and ninety five consecutive patients largely of middle, lower income groups. All examinations were performed using a linear array real-time (dynamic image) sonographic system.

The anatomic plane chosen for head measurements was the axial plane described by Hadlock et al 1982 (6) for measurement of the fetal occipito-frontal diameter.

Gain settings were adjusted giving the skull width a sharp outline. All measurements were made using either a hand held map measurer or an electronic digitizer. Tracing of the head was along the outer perimeter of the calvarium. Each fetus was measured only once in pregnancy.

Abdominal Circumference

Measurement is performed the same way as that of the head circumference.

This was done by using a digitizer and in some cases a map reader to trace the outer limits of the fetal body.

Abdominal circumference was measured by tracing the outer margin of the abdomen. The plane of section was through the liver, umbilical vein and stomach.

The relation between fetal abdominal circumference and menstrual age was determined for 281 foetuses 15-42 weeks; examined with a linear array real time ultrasound scanner. Mathematical modeling was done on linear quadratic, and linear cubic regressions. Results obtained are displayed graphically. Comparing to works by other investigators, it is shown that abdominal circumference measurements are amenable to mathematical foetal weight manipulation. For predicting foetal gestation age in the third trimester, fetal abdominal circumference gave consistent results - Hadlock P.F. et al(17,25), Campbell et al(3).

Fetal femoral length was measured with a linear array transducer, real time ultrasound scanner in 284 uncomplicated gravid patients who knew their menstrual age reliably.

This covered gestation age from 14 weeks till 42 weeks. To measure the femoral length transducers used were 3.5 megahertz (MHz) frequencies with a velocity calibration of 1540 megahertz per second.

A freeze frame was employed once the full length of the femur was visualized.

The length of the calcified portion of the femur was measured. Data obtained was subjected to statistical analysis.

Linear and non-linear cubic regression was performed on the observations for biparietal diameter, head circumference, abdominal circumference and femur length. Non-linear regression provided the best line of goodness of fit using the cubic equation for all the above mentioned parameters.

The equation for biparietal diameter was:-

Biparietal diameter = $-2.416 + 0.405\ MA^2 - 7.70 \times 10^{-5}\ MA^3$

(M.A. = Menstrual Age)

The equation for head circumference was:-

Head circumference = $-8.206 + 1.459\ MA - 2.83 \times 10^{-4}\ MA^3$

The equation for abdominal circumference was:-

Abdominal circumference = $-8.306 + 1.278\ MA - 1.88 \times 10^{-4}\ MA^3$

The equation for femur length was:-

Femur length = $-2.640 + 0.329\ MA - 5.39 \times 10^{-5}\ MA^3$

The goodness of fit (R^2) for the above lines were:-

Biparietal diameter	80.383%
Head circumference	84.999%
Abdominal circumference	79.578%
Femur length	81.366%

The above statistics were done using the SPSS statistical package.

NOTE:

1. Non-linear - regression is used interchangeably with linear cubic.
2. M.A. = Menstrual age.

RESULTS

Section A:

Many mothers were young as 81.3% or 278 were thirty years of age or below. (Histogram figure 1).

Marital Status: Most were married, 50 women were single and 3 either divorced, widowed or separated. No information is available for twenty-two women or 5.57% of 395 women. See Histogram of marital status. (Histogram figure 2).

Monthly Income: They were largely low income earners with 84.4% (248) of a valid number of 294 earning or spending less than KShs.4,000 per month. No information was available for the remaining 101 women. (See Fig. 3).

Menstrual age in weeks: Only one patient presented at gestation age 14 weeks and two at 43-44 weeks. Most women presented for obstetric ultrasonography at a gestation age of thirty-six weeks - 30 patients. Those unsure of dates were 104 or 26.3%. (See histogram Figure 4). Those women for whom parity was given were 350. Those who had delivered three or fewer children made up 92.9% of 350 (325). Further 121 women were nulliparous constituting 34.6% valid percent. (See histogram Figure 5). Foetal loss was as follows:-

Average is 0.479 foetal per pregnant woman examined i.e $186/395 \times 100$. (See histogram Figure 6).

Placental position - The commonest placental location is anterior followed by fundoposterior. Previa were 4 cases out of 370 valid cases hence $\simeq$ 1.1%. (See Histogram Fig. 7).

Section B:

Results of Means Versus Menstrual Age

The means of this study are presented in graphic form; such as the mean of biparietal diameter in cm versus menstrual age in weeks ($\pm$2 S.D.). This is followed by a table of means of this study compared to that of Yagel et al 1986. A graph of comparison between means of B.P.D. in cm versus menstrual age in this study versus Yagel et al is presented. A similar graph of this study and Rogo et al, Dhadialla and Osefo et al. is presented (7,9,12).

The other means whose results subsequently follow are for head circumference, femoral length and abdominal circumference versus menstrual age. Graphs of comparisons with studies done elsewhere are given. (See Figures 8-18, Tables 1-6).

Results are presented between pages 22 and 64, both inclusive.

Sociodemographic Data is summarised and presented on histograms. They cover a wide range of results based on statistics carried out with a maximum of three hundred and ninety-five women. Here also emphasis is placed only on those with complete information. (see Appendix II on page 80).

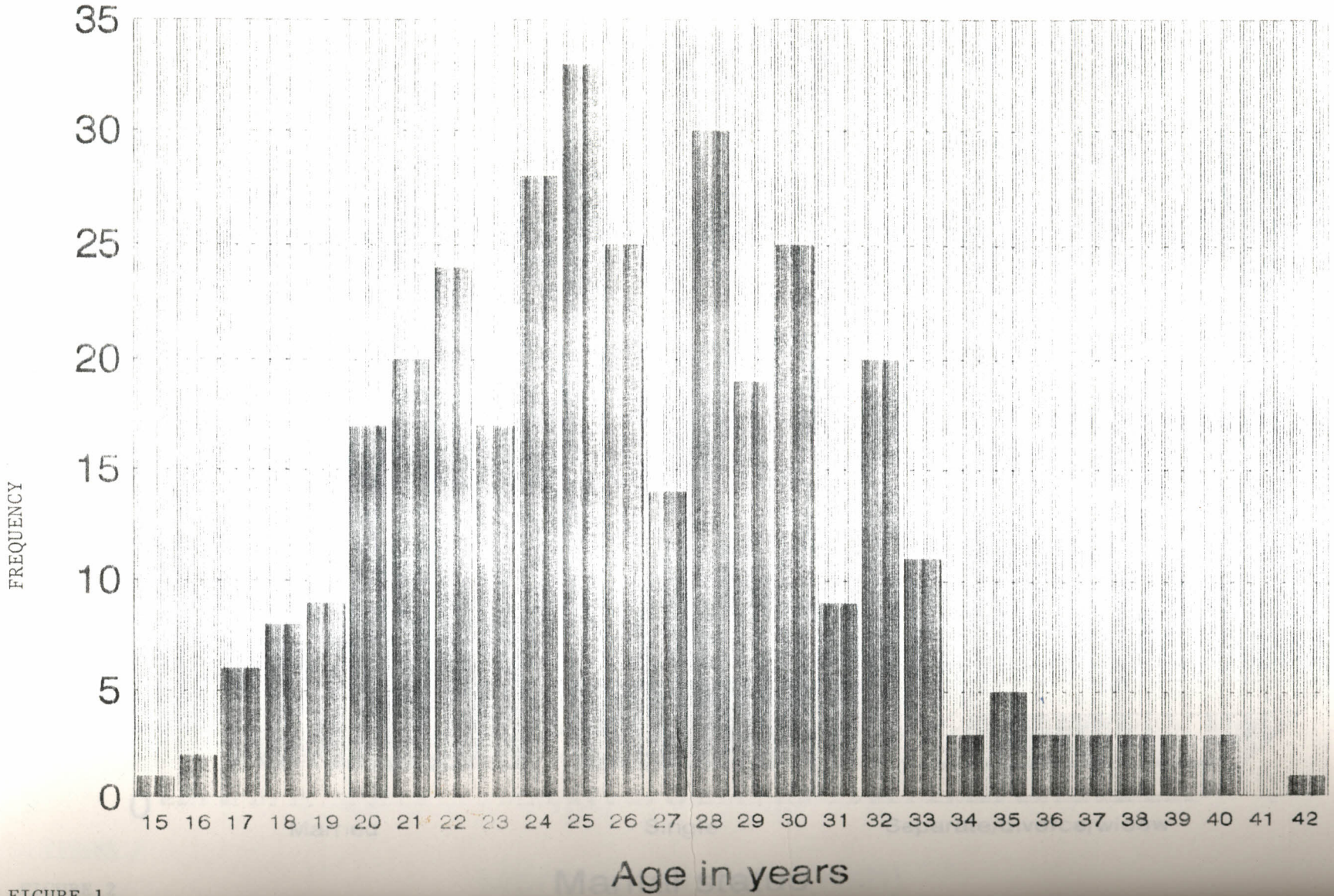
Presentation of Means: The order is as follows:-

(1) This study on a barline graph for biparietal diameter, head circumference, femoral length and abdominal circumference.

(2) Tables of menstrual age in weeks, measurements in this study and that of Yagel or Hadlock as appropriate. Also with Rogo, Osefo, Dhadialla and Qureshi.

(3) Graphs representative of number 2 above.

Please note; descriptive legend for tables and graphs is given on appendices ii,iii & iv on pages 80-82.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10
15
20
25
30
35
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
Age in years

FIGURE 1

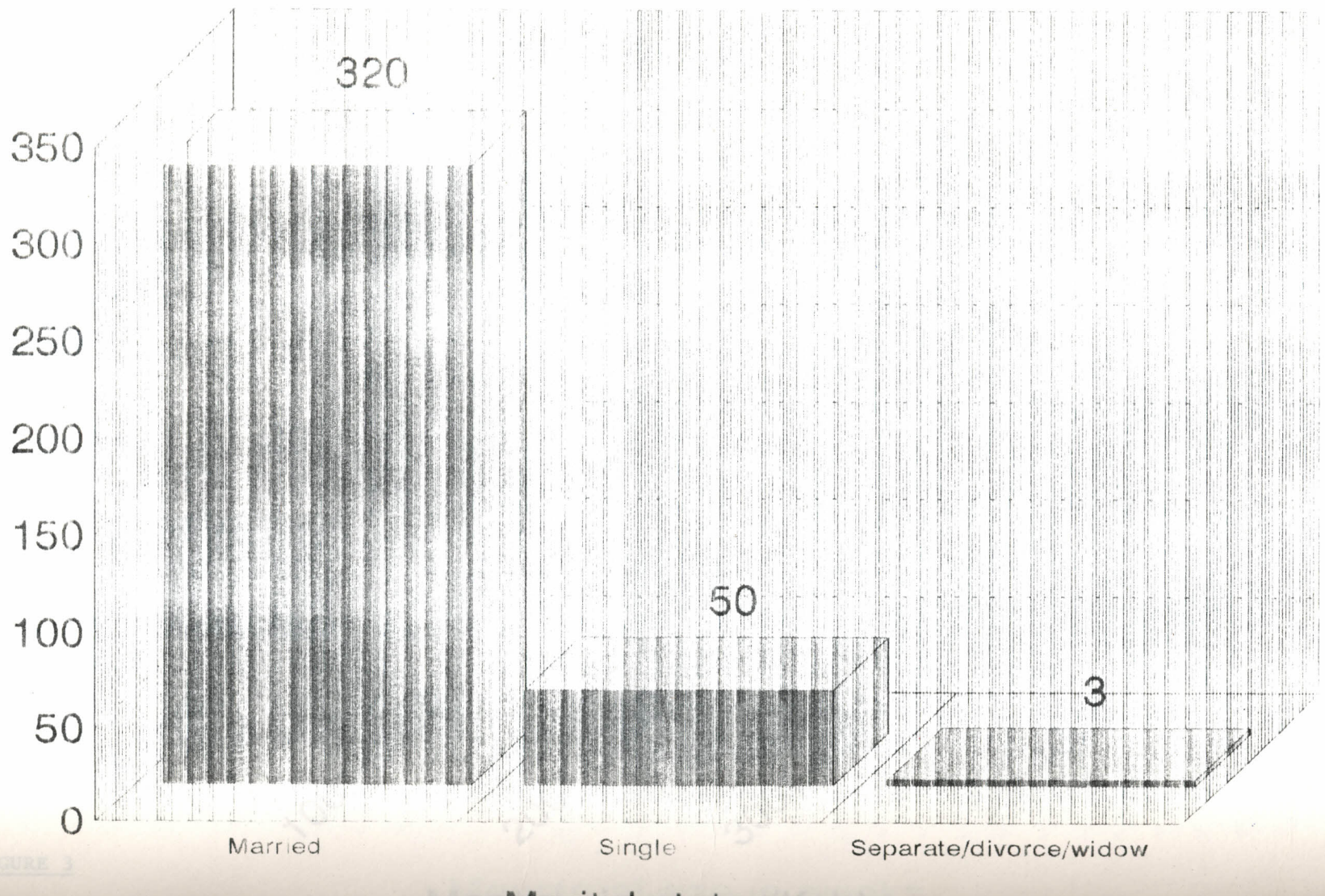

320
50
3
350
300
250
200
150
100
50
0
FREQUENCY
Married
Single
Separate/divorce/widow
Marital status

FIGURE 2

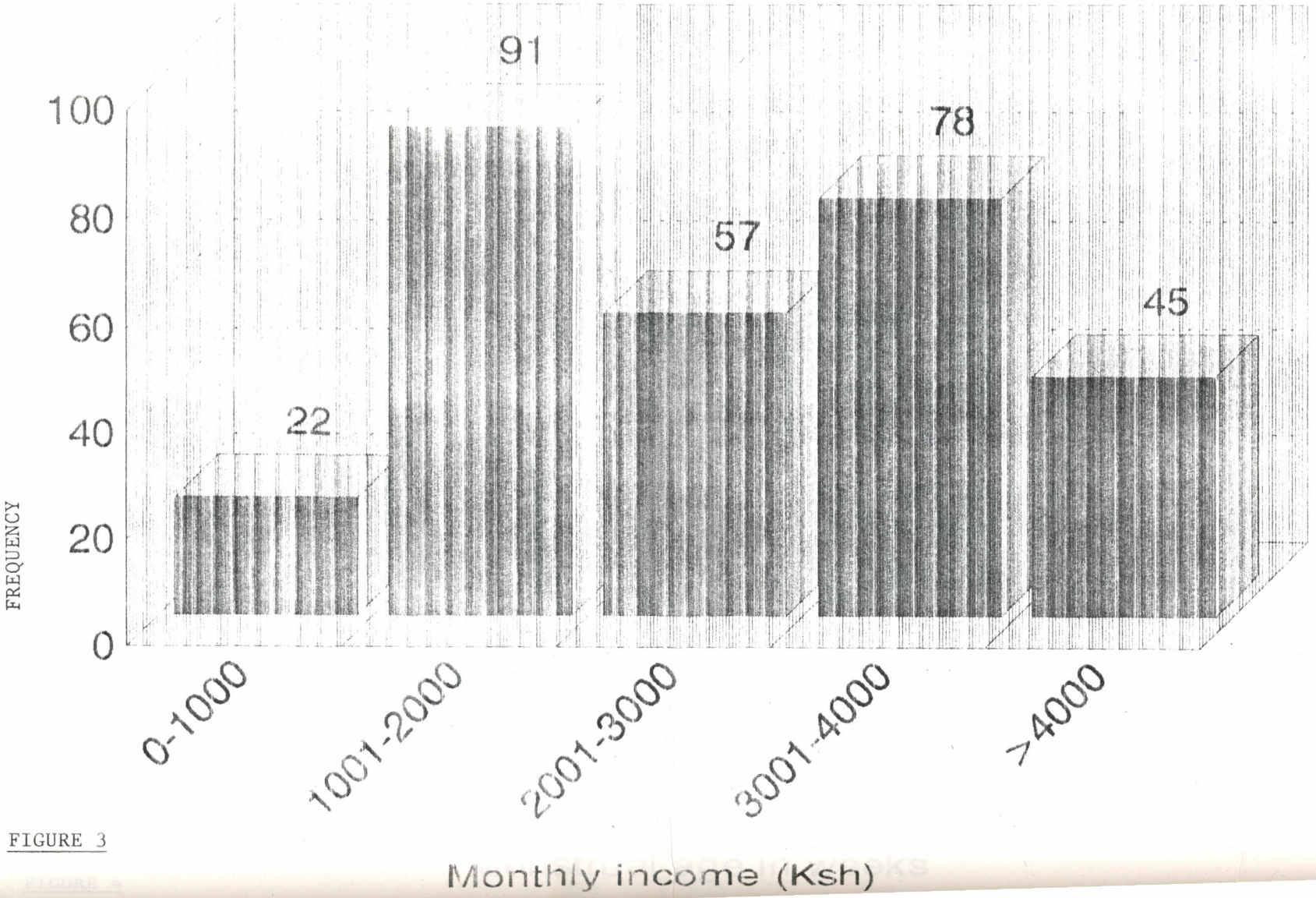
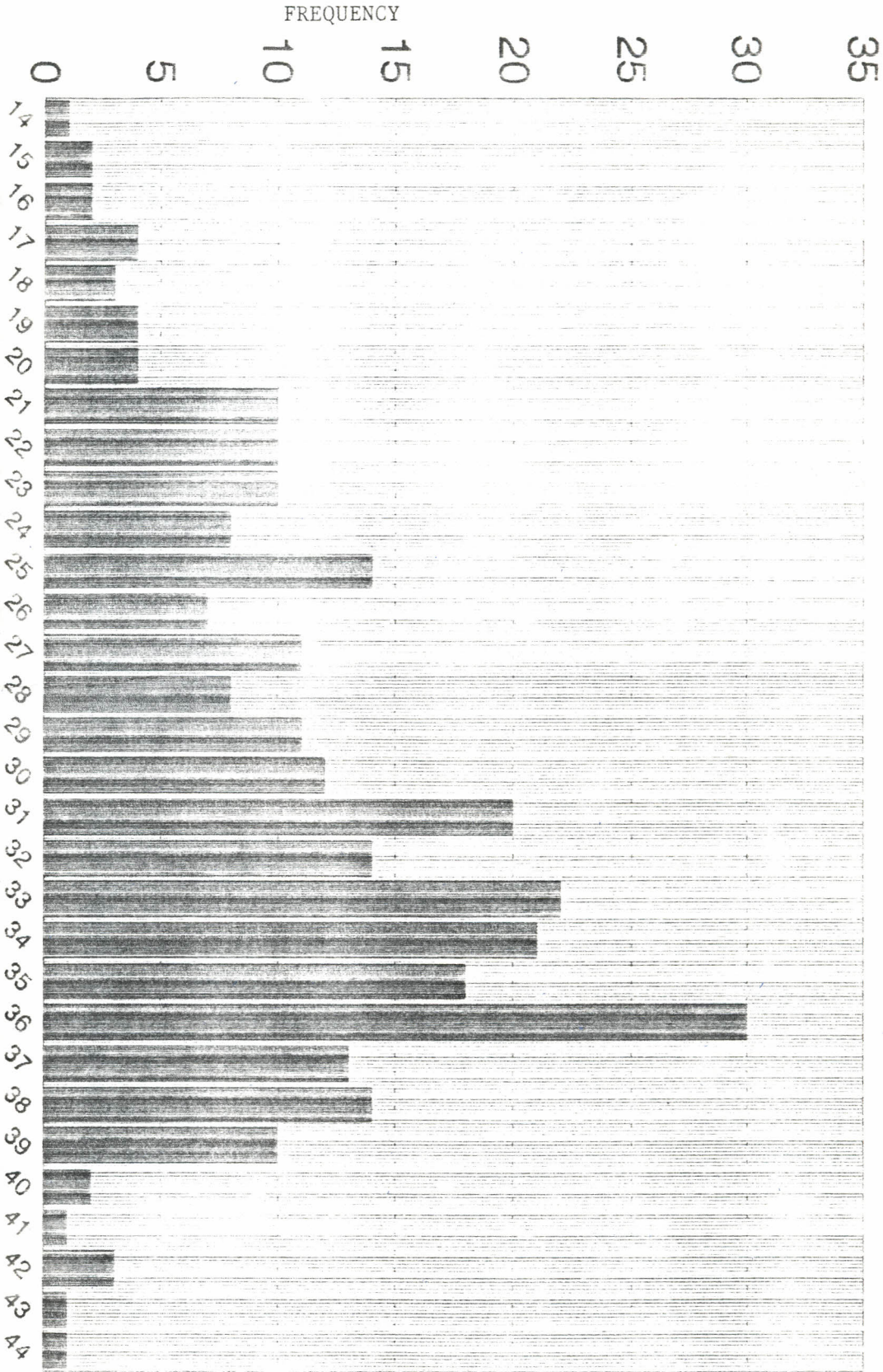

91
78
57
45
22
100
80
60
40
20
0
FREQUENCY
0-1000
1001-2000
2001-3000
3001-4000
>4000
Monthly income (Ksh)

FIGURE 3

FIGURE 4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25
26
27
28
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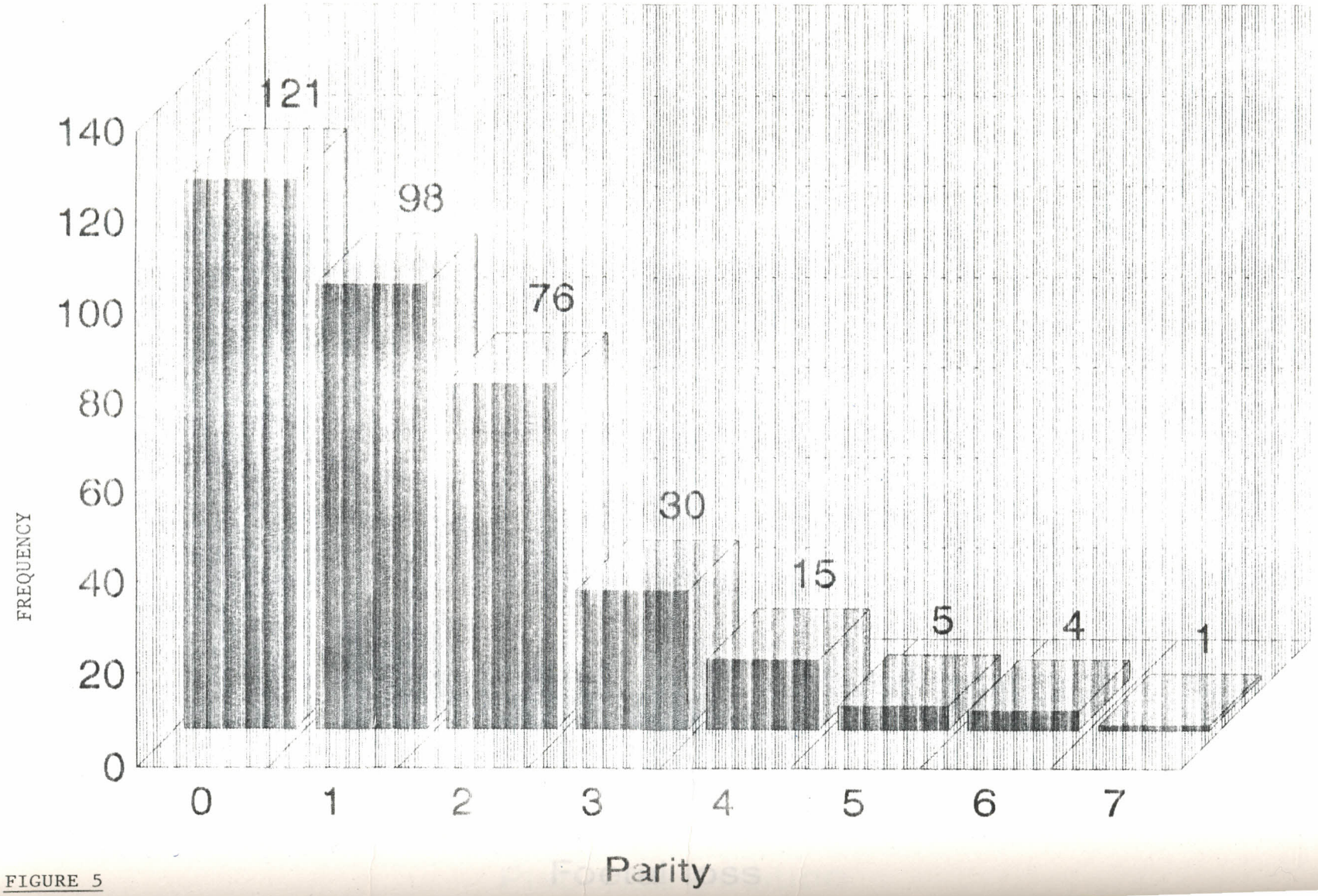
39
40
41
42
43
44
Menstrual age in weeks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15
5
4
1
140
120
100
80
60
40
20
0
FREQUENCY
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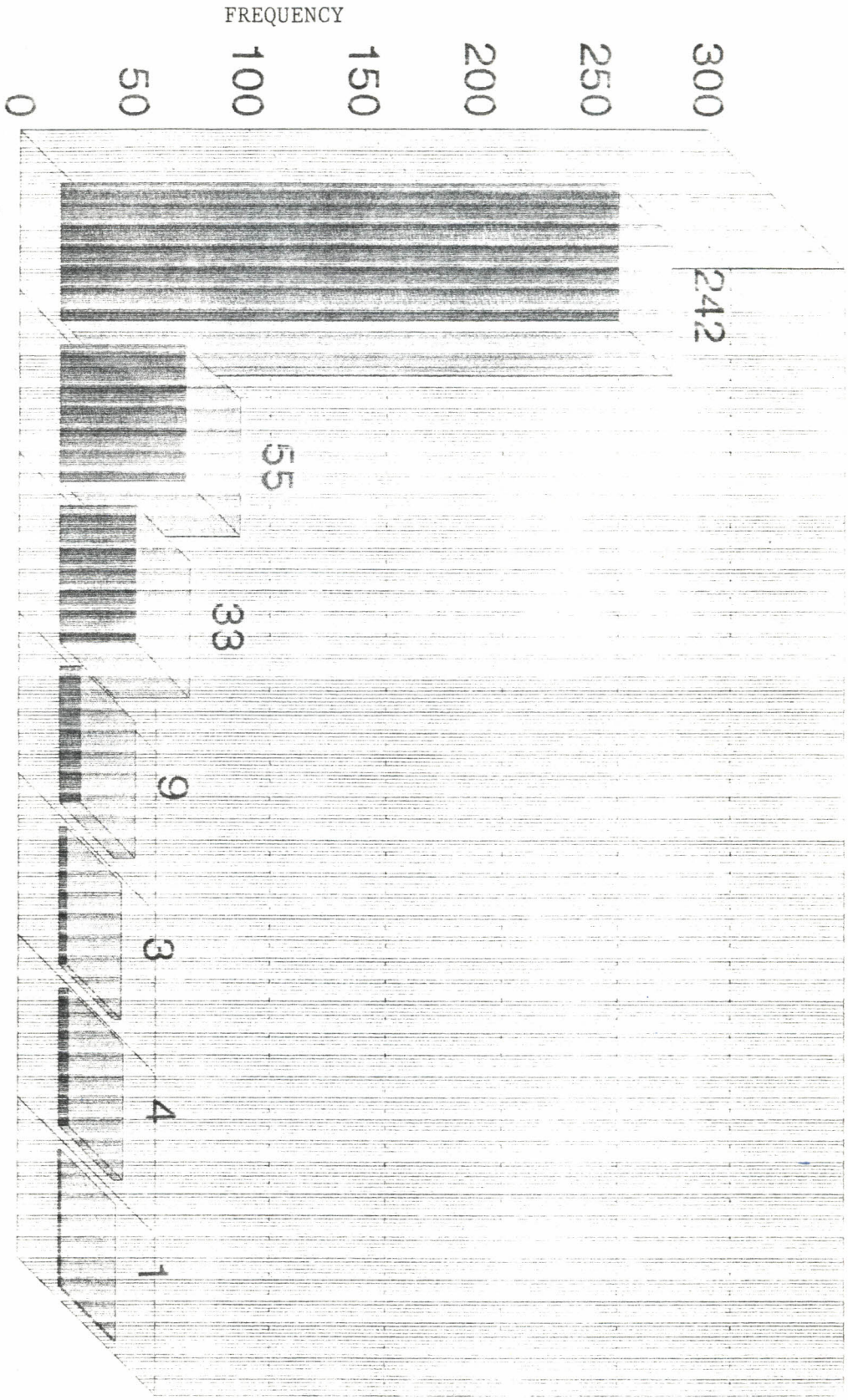
1
2
3
4
5
6
7
Parity

FIGURE 5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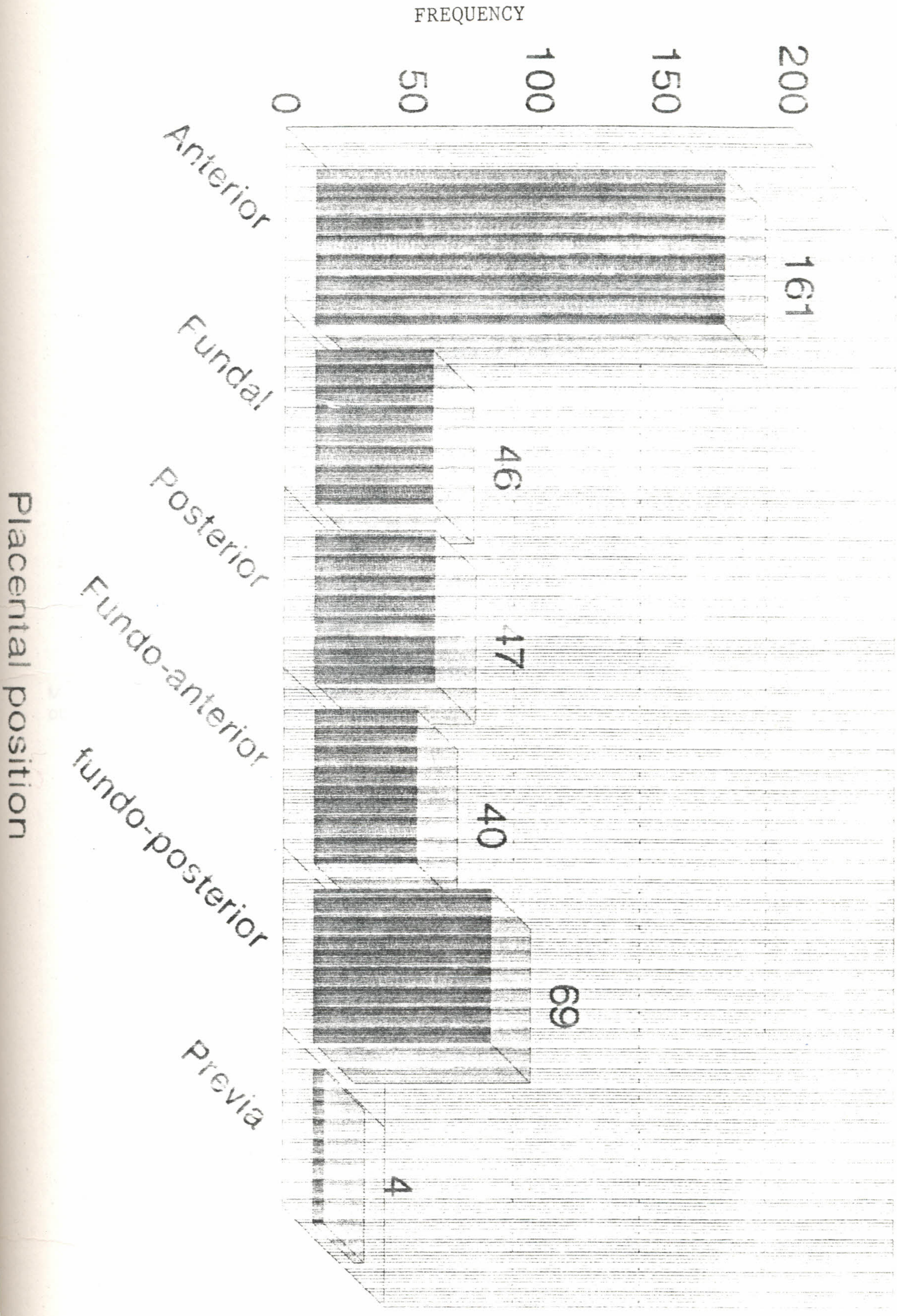
2
3
4
5
6
Foetal loss

FIGURE 7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100
150
200
Anterior
Fundal
Posterior
Fundo-anterior
fundo-posterior
Previa
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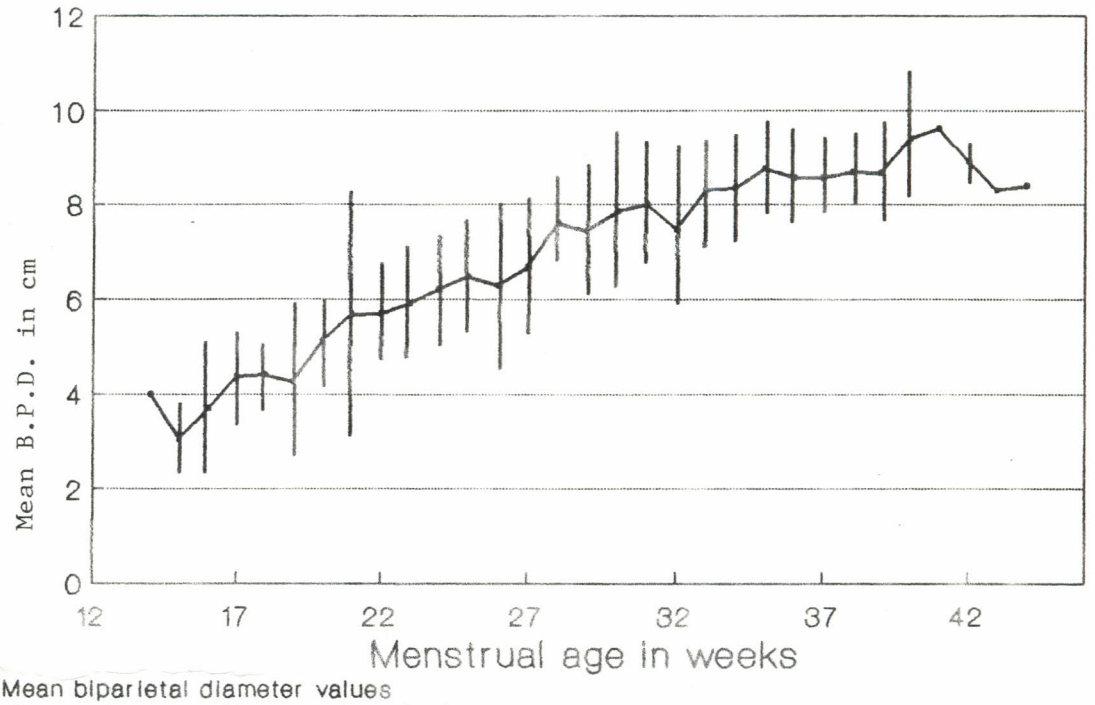
46
47
40
69
4
Placental position



Mean biparietal diameter values
observed at specific weeks(+or-2sd)

FIGURE 8

Table of mean biparietal diameter values at specific weeks in gestation; Comparison between this study and Yagel et al (1986)

	THIS STUDY			Yagel et al (1986)		
Menstrual age	Mean B.P.D.	One stddev	No. of Cases	Mean B.P.D.	One stddev	No. of Cases
14	4.0000	0.0000	1	2.733	0.219	12
15	3.0500	0.3536	2	2.987	0.262	23
16	3.7000	0.7071	2	3.397	0.204	35
17	4.3750	0.4787	4	3.653	0.261	38
18	4.4000	0.3464	3	3.936	0.238	25
19	4.2500	0.8426	4	4.336	0.220	31
20	5.1250	0.4349	4	4.708	0.258	25
21	5.6800	1.2934	10	5.018	0.286	28
22	5.7000	0.5050	9	5.280	0.325	30
23	5.9000	0.6236	10	5.407	0.307	41
24	6.2000	0.5782	8	5.808	0.358	39
25	6.4769	0.5946	13	6.204	0.327	49
26	6.2857	0.8474	7	6.509	0.425	33
27	6.6818	0.6780	11	6.662	0.457	52
28	7.5875	0.4794	8	7.091	0.371	47
29	7.4364	0.7187	11	7.325	0.340	48
30	7.8500	0.8555	12	7.585	0.390	59
31	8.0150	0.6532	20	7.818	0.403	62
32	7.4857	0.8475	14	8.108	0.364	66
33	8.3000	0.5390	22	8.200	0.416	61
34	8.3524	0.5645	21	8.457	0.363	68
35	8.7556	0.5147	18	8.570	0.365	54
36	8.5767	0.5348	30	8.761	0.337	61
37	8.5692	0.4029	13	8.926	0.368	43
38	8.6857	0.3997	14	8.989	0.410	35
39	8.6600	0.5232	10	9.206	0.365	33
40	9.4000	0.7071	2	9.100	0.389	10
41	9.6000	0.0000	1	9.117	0.286	6
42	8.9333	0.2082	3	-	-	-
43	8.3000	0.0000	1	-	-	-
44	8.4000	0.0000	1	-	-	-

TABLE 1

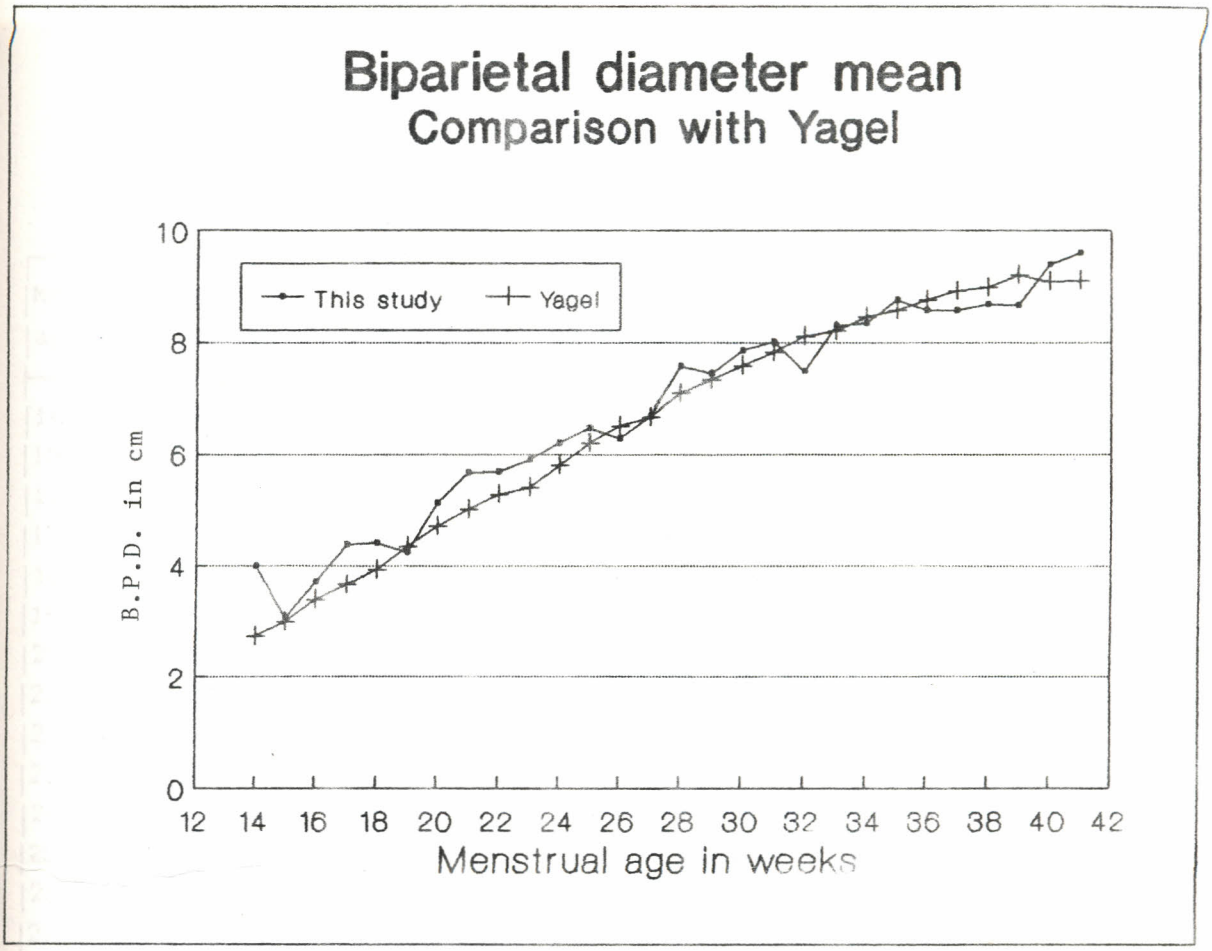

Biparietal diameter mean
Comparison with Yagel
This study
Yagel
B.P.D. in cm
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
Menstrual age in weeks

FIGURE 9

Table of mean biparietal diameter at specific weeks in gestation
Comparison between this study and Osefo, Rogo & Dhadialla

	THIS STUDY	OSEFO	ROGO	DHADIALLA
Menstrual age	Mean B.P.D.	Mean B.P.D.	Mean B.P.D.	Mean B.P.D.
14	4.0000	-	-	-
15	3.0500	-	-	-
16	3.7000	-	-	-
17	4.3750	-	-	-
18	4.4000	-	-	-
19	4.2500	-	-	-
20	5.1250	4.88	4.89	4.77
21	5.6800	-	-	-
22	5.7000	5.50	5.56	5.49
23	5.9000	-	-	-
24	6.2000	5.81	6.09	5.98
25	6.4769	-	-	-
26	6.2857	6.41	6.66	6.58
27	6.6818	-	-	-
28	7.5875	6.93	7.04	7.21
29	7.4364	-	-	-
30	7.8500	7.53	7.31	7.67
31	8.0150	-	-	-
32	7.4857	7.86	7.72	8.23
33	8.3000	-	-	-
34	8.3524	8.37	8.19	8.62
35	8.7556	-	-	-
36	8.5767	8.82	8.65	8.92
37	8.5692	-	-	-
38	8.6857	9.06	8.89	9.21
39	8.6600	-	-	-
40	9.4000	9.33	9.23	9.46
41	9.6000	-	-	-
42	8.9333	-	-	-
43	8.3000	-	-	-
44	8.4000	-	-	-

TABLE 2

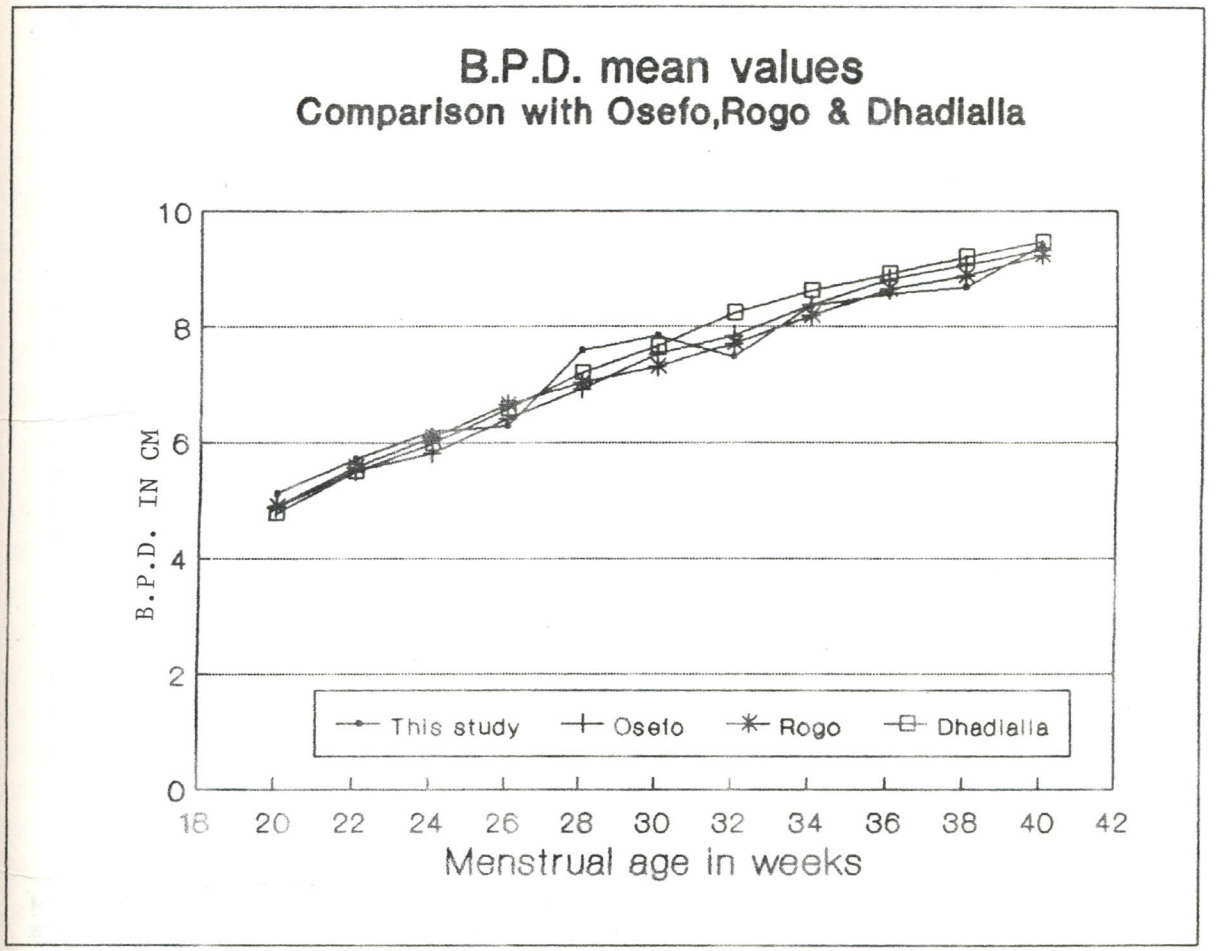
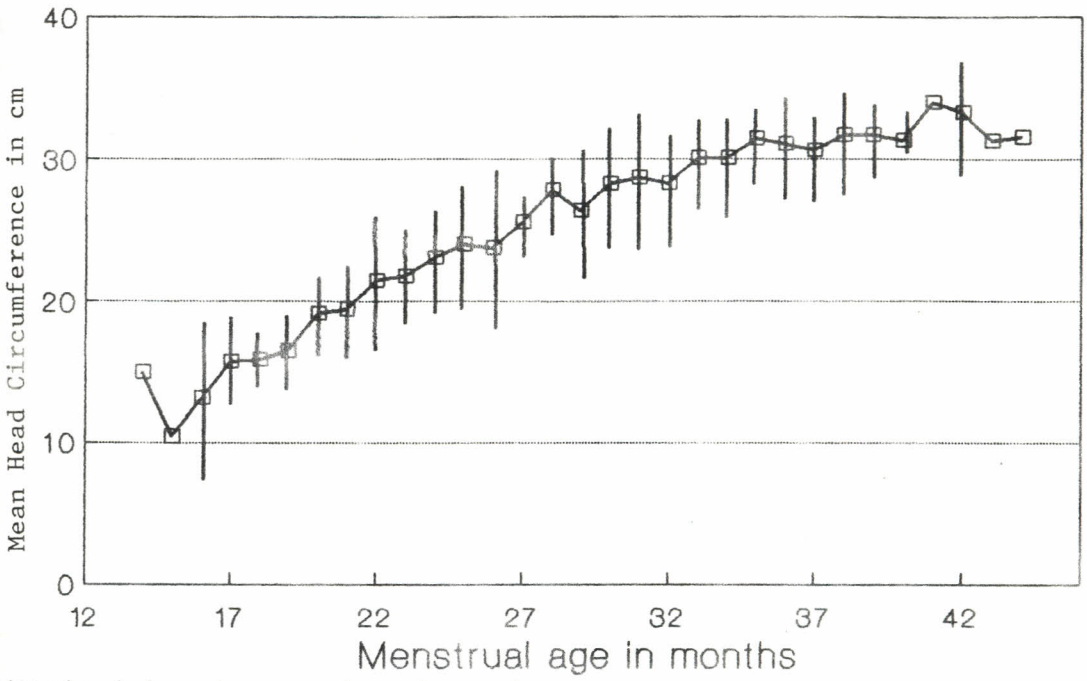

B.P.D. mean values
Comparison with Osefo,Rogo & Dhadlalla
B.P.D. IN CM
10
8
6
4
2
0
This study
Osefo
Rogo
Dhadlalla
18
20
22
24
26
28
30
32
34
36
38
40
42
Menstrual age in weeks

FIGURE 10



Mean head circumference values observed
at specific weeks in gestation(+or-2sd)

FIGURE 11

Table of mean head cicumference at specific weeks in gestation; Comparison between this study and Hadlock(1982)

	THIS STUDY			HADLOCK et al 1982		
Menstrual age	Mean H.C.	One stddev	No. of cases	Mean H.C.	One stddev	No. of cases
14	15.0000	0.0000	1	-	-	-
15	10.4000	0.0000	1	11.4	0.38	5
16	13.1500	2.7577	2	12.2	1.23	15
17	15.7667	1.5948	3	13.4	0.69	18
18	15.8667	1.1060	3	14.8	0.66	10
19	16.4667	1.3577	3	16.0	1.14	17
20	19.1000	1.3241	4	17.7	1.16	17
21	19.4143	1.6906	7	18.2	0.85	15
22	21.4444	2.3812	9	19.3	1.16	16
23	21.7700	1.7179	10	20.8	1.07	13
24	23.0500	1.8769	8	22.1	0.78	21
25	24.0308	2.1853	13	23.9	1.34	10
26	23.7800	2.9227	5	24.1	1.21	13
27	25.5400	1.0926	10	25.6	1.04	14
28	27.8375	1.3585	8	27.1	1.51	9
29	26.4091	2.2726	11	27.3	1.15	12
30	28.2333	2.2268	12	27.7	0.80	10
31	28.6850	2.5808	20	28.1	1.12	12
32	28.3000	2.1162	12	29.2	0.71	12
33	30.0600	1.6794	20	30.2	1.13	12
34	30.0889	1.6413	18	30.9	1.00	17
35	31.4722	1.3345	18	31.7	1.23	8
36	31.1033	1.9045	30	32.2	0.94	11
37	30.6308	1.5190	13	33.0	1.16	8
38	31.7071	1.9105	14	33.6	0.76	32
39	31.7000	1.3666	9	34.0	0.90	44
40	31.3000	0.2828	2	34.5	0.81	25
41	34.0000	0.0000	1	35.4	0.98	4
42	33.3000	1.9975	3	-	-	-
43	31.3000	0.0000	1	-	-	-
44	31.6000	0.0000	1	-	-	-

TABLE 3

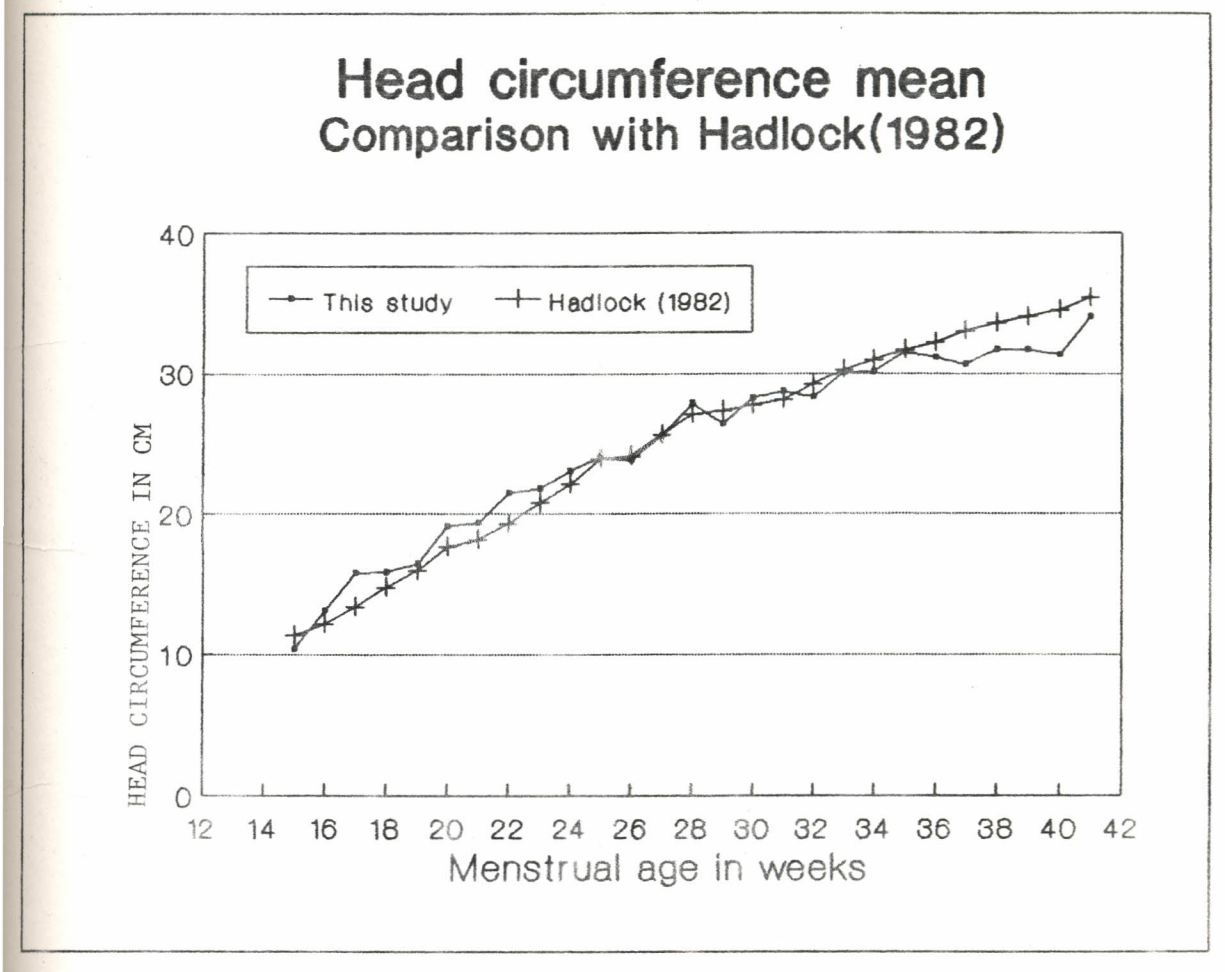
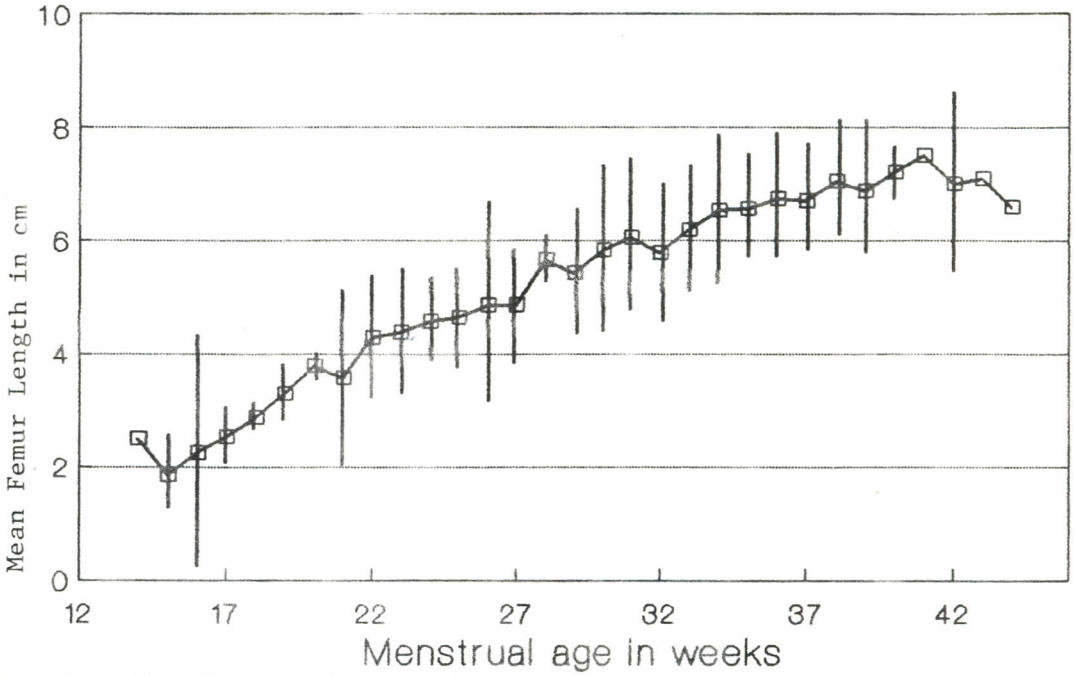

Head circumference mean
Comparison with Hadlock(1982)
This study
Hadlock (1982)
HEAD CIRCUMFERENCE IN CM
0
10
20
30
40
12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Menstrual age in weeks

FIGURE 12



Mean femur length values observed at specific weeks in gestation(+or-2sd)

FIGURE 13

Table of means of femur length at specific weeks of gestation; Comparison between this study and Yagel et al (1986)

	THIS STUDY			YAGEL et al (1986)		
Menstrual Age	Mean F.L.	One stddev	No. of Cases	Mean F.L.	One stddev	No. of Cases
14	2.5000	0.0000	1	1.442	0.250	12
15	1.8500	0.3536	2	1.609	0.202	23
16	2.2500	1.0607	2	1.914	0.251	35
17	2.5250	0.2754	4	2.092	0.216	38
18	2.8667	0.1155	3	2.412	0.199	25
19	3.3000	0.2646	3	2.865	0.162	31
20	3.7750	0.1258	4	3.204	0.232	25
21	3.5750	0.7704	8	3.461	0.231	28
22	4.2800	0.5391	10	3.737	0.279	30
23	4.3700	0.5539	10	3.912	0.236	42
24	4.5625	0.3852	8	4.213	0.296	39
25	4.6429	0.4620	14	4.530	0.277	50
26	4.8667	0.9004	6	4.745	0.292	33
27	4.8545	0.4865	11	4.936	0.331	53
28	5.6500	0.2000	8	5.157	0.319	47
29	5.4364	0.5626	11	5.402	0.254	48
30	5.8333	0.7240	12	5.632	0.297	59
31	6.0550	0.6901	20	5.782	0.295	62
32	5.7846	0.5998	13	6.121	0.265	67
33	6.1818	0.5500	22	6.224	0.241	62
34	6.5263	0.6505	19	6.427	0.263	70
35	6.5611	0.4730	18	6.545	0.220	55
36	6.7433	0.5905	30	6.767	0.296	61
37	6.7000	0.5164	13	6.919	0.342	43
38	7.0429	0.5543	14	7.057	0.262	35
39	6.8800	0.6250	10	7.174	0.256	34
40	7.2000	0.1414	2	7.250	0.317	10
41	7.5000	0.0000	1	7.450	0.327	6
42	7.0000	0.7810	3	-	-	-
43	7.1000	0.0000	1	-	-	-
44	6.6000	0.0000	1	-	-	-

TABLE 4

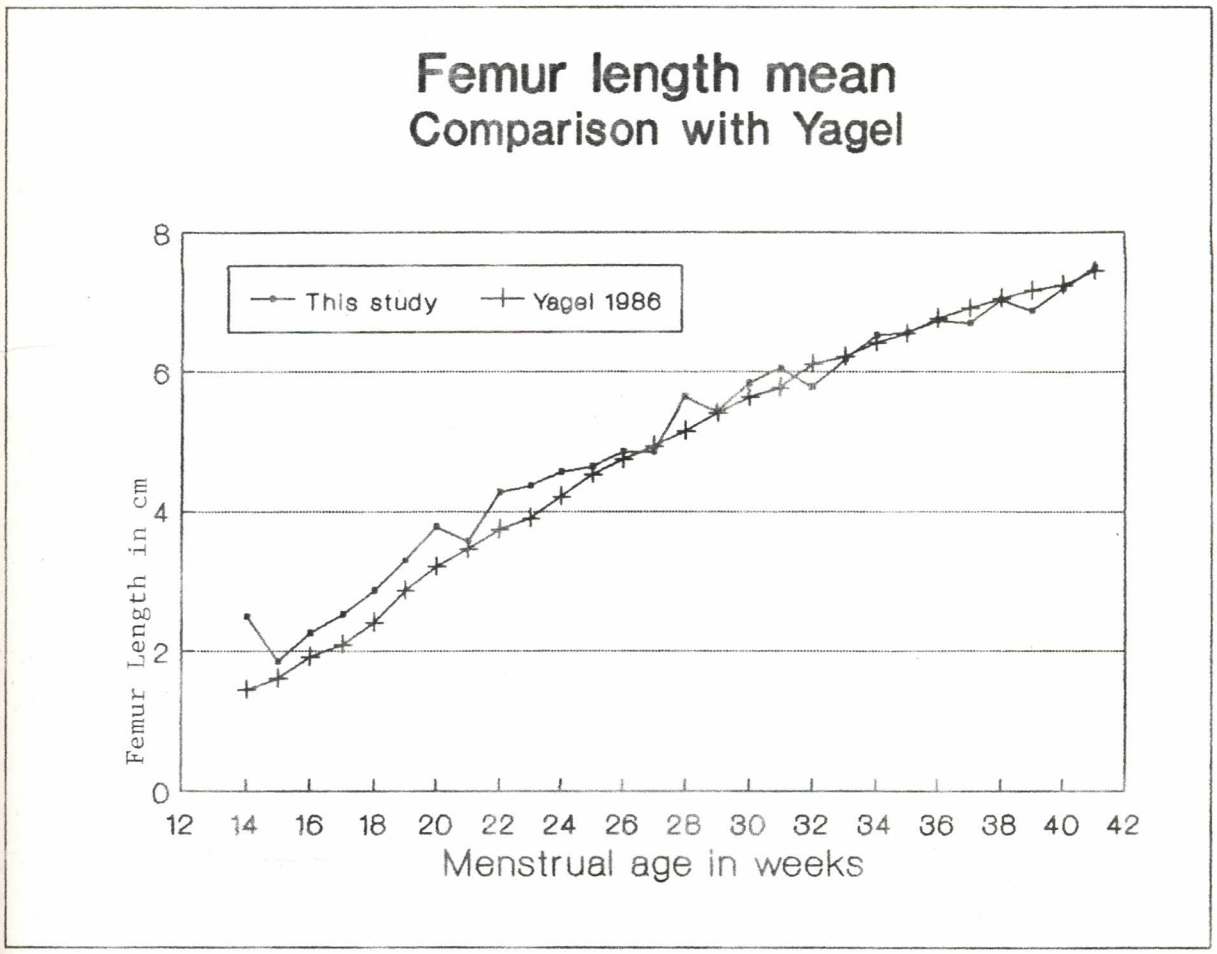

Femur length mean
Comparison with Yagel
This study
Yagel 1986
Femur Length in cm
0
2
4
6
8
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
Menstrual age in weeks

FIGURE 14

Means of femur length as per menstual age
Comparison with Quresh Z.P.(1989)

	THIS STUDY			QURESH		
Menstrual age; weeks	Mean F.L.	No. of Cases	Two stddev	Mean F.L.	No. of Cases	Two stddev
14	2.5000	1	0.0000	1.55	11	0.30
15	1.8500	2	0.7072	1.96	12	0.50
16	2.2500	2	2.1214	2.08	10	0.32
17	2.5250	4	0.5508	2.35	11	0.88
18	2.8667	3	0.2310	2.65	11	0.60
19	3.3000	3	0.5292	3.04	14	0.74
20	3.7750	4	0.2516	3.43	16	0.72
21	3.5750	8	1.5408	3.60	15	0.76
22	4.2800	10	1.0782	3.86	13	0.58
23	4.3700	10	1.1078	4.02	14	0.94
24	4.5625	8	0.7704	4.53	20	1.04
25	4.6429	14	0.9240	4.59	23	0.54
26	4.8667	6	1.8008	4.99	24	1.06
27	4.8545	11	0.9730	5.15	21	0.86
28	5.6500	8	0.4000	5.35	21	0.64
29	5.4364	11	1.1252	5.40	22	0.80
30	5.8333	12	1.4480	5.78	26	0.84
31	6.0550	20	1.3802	5.96	27	0.82
32	5.7846	13	1.1996	6.20	22	0.68
33	6.1818	22	1.1000	6.36	32	0.88
34	6.5263	19	1.3010	6.59	27	0.66
35	6.5611	18	0.9460	6.71	33	0.52
36	6.7433	30	1.1810	6.87	31	0.68
37	6.7000	13	1.0328	7.00	21	0.40
38	7.0429	14	1.1086	7.16	26	0.82
39	6.8800	10	1.2500	7.27	21	0.62
40	7.2000	2	0.2828	7.37	15	0.70
41	7.5000	1	0.0000	7.40	10	0.60
42	7.0000	3	1.5620	-	-	-
43	7.1000	1	0.0000	-	-	-
44	6.6000	1	0.0000	-	-	-

TABLE 5

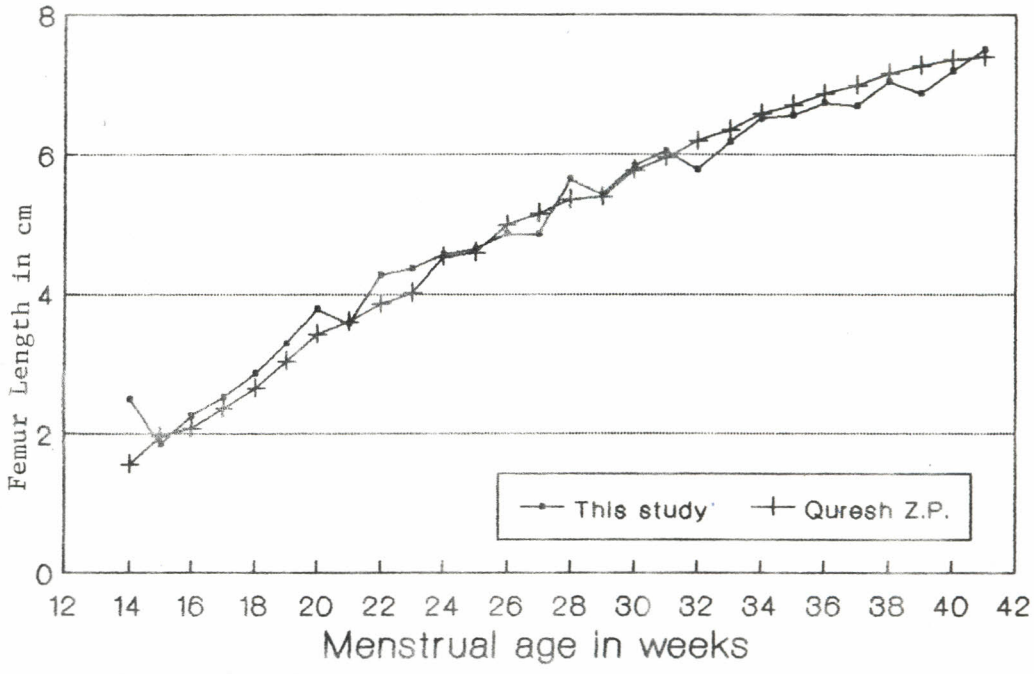
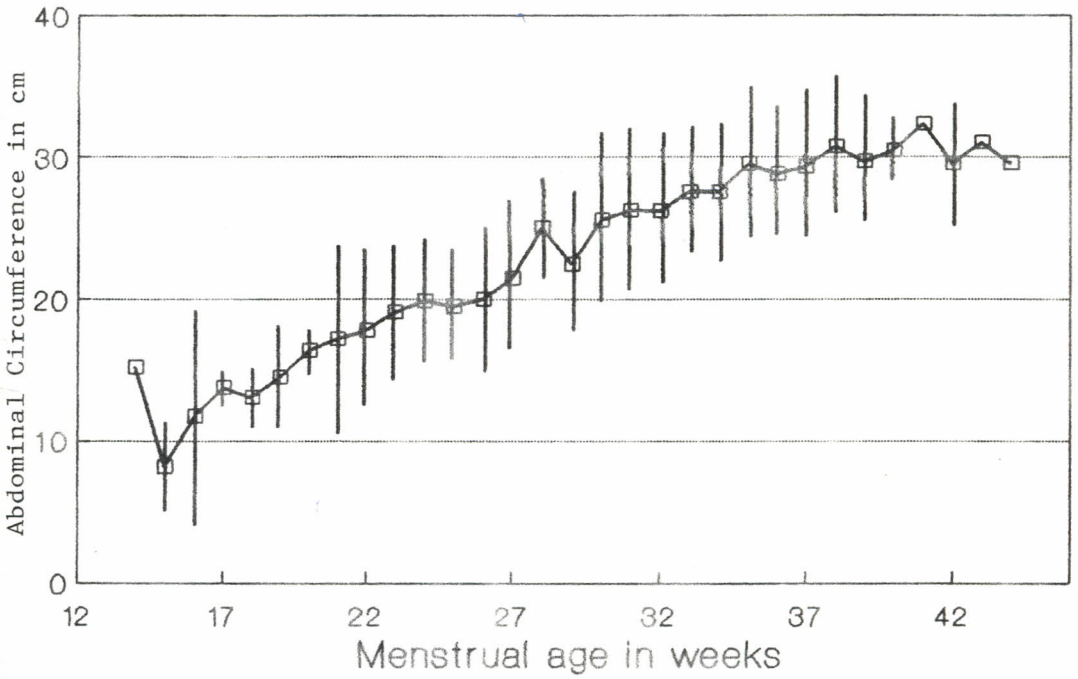

Femur length mean
Comparison with Quresh
Femur Length in cm
0
2
4
6
8
12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Menstrual age in weeks
This study
Quresh Z.P.

FIGURE 15



Mean abdominal circumference values
observed at specific weeks(+or-2sd)

FIGURE 16

Table of mean abdominal circumference values at specific weeks in gestation; Comparison between this study and Hadlock et al (1982)

	THIS STUDY			HADLOCK et al (1982)		
Menstrual age	A.C. Mean	One stddev	No. of cases	A.C. Mean	One stddev	No. of cases
14	15.2000	0.0000	1	-	-	-
15	8.1500	1.4849	2	9.87	0.53	5
16	11.7500	3.7477	2	10.47	1.14	15
17	13.7500	0.6403	4	11.36	0.86	18
18	13.0333	1.0693	3	12.77	0.83	10
19	14.4667	1.8771	3	13.58	1.43	17
20	16.3750	0.6500	4	15.49	1.29	17
21	17.2000	3.2615	8	15.82	1.00	15
22	17.8100	2.9080	10	16.91	1.38	16
23	19.0400	2.4487	10	18.72	1.81	13
24	19.8500	2.0674	8	19.72	1.01	21
25	19.4769	1.8780	13	21.36	0.97	10
26	20.0000	2.5955	7	22.08	1.25	13
27	21.4636	2.6882	11	23.09	0.97	14
28	24.9875	1.7537	8	24.66	1.55	9
29	22.4636	2.4853	11	25.00	1.08	12
30	25.5667	3.0043	12	25.21	1.32	10
31	26.2368	2.9532	19	26.59	1.38	12
32	26.1917	2.6845	12	27.15	0.87	12
33	27.5864	2.2331	22	28.90	1.37	12
34	27.5579	2.5178	19	29.78	1.36	17
35	29.4833	2.7408	18	30.46	1.23	8
36	28.8100	2.2715	30	31.22	1.15	11
37	29.3385	2.6729	13	32.95	1.46	8
38	30.7714	2.4938	14	33.93	1.39	32
39	29.6889	2.2597	9	34.51	1.49	44
40	30.4500	1.0607	2	34.91	1.29	25
41	32.3000	0.0000	1	35.43	0.42	4
42	29.5000	2.0881	3	-	-	-
43	31.0000	0.0000	1	-	-	-
44	29.6000	0.0000	1	-	-	-

TABLE 6

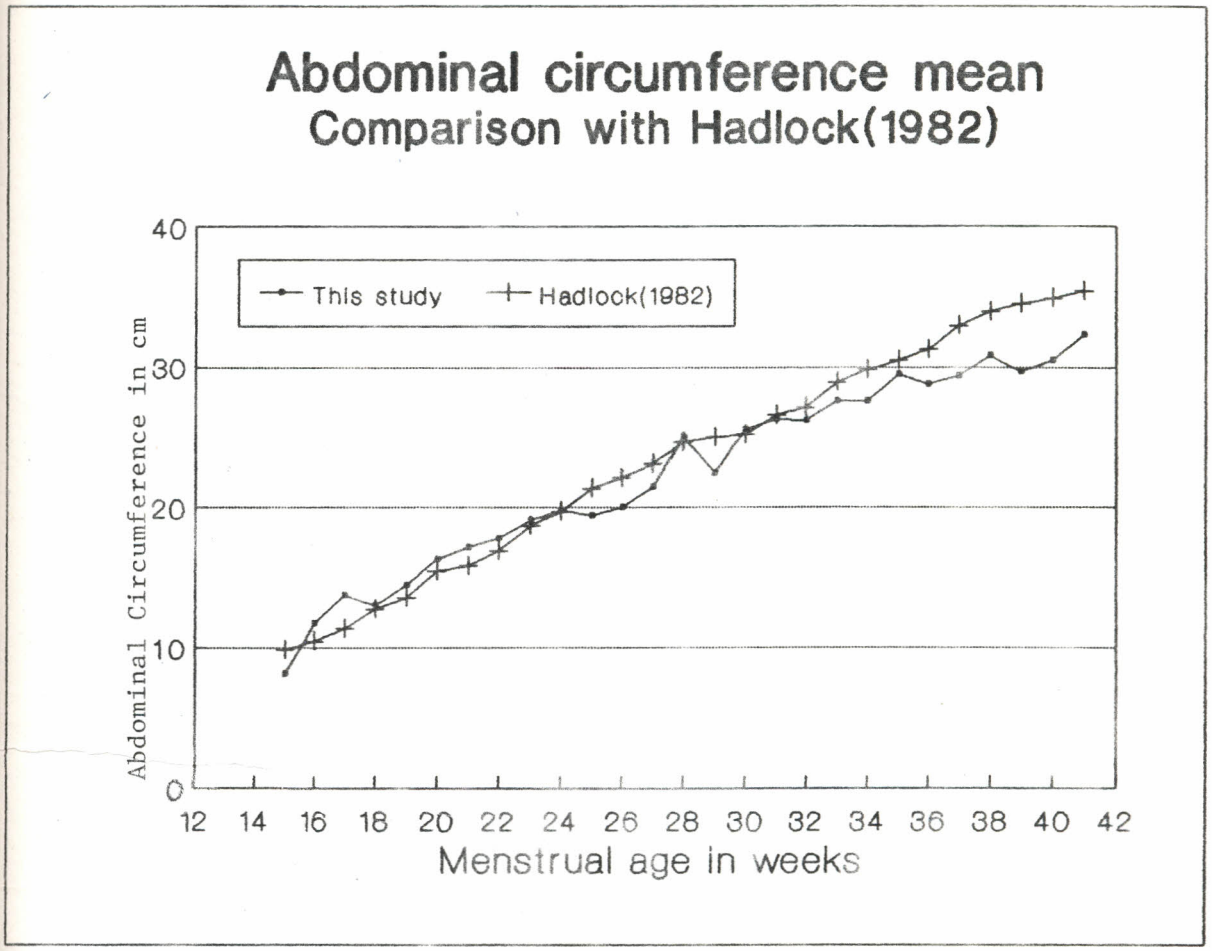

Abdominal circumference mean
Comparison with Hadlock(1982)
This study
Hadlock(1982)
Abdominal Circumference in cm
0
10
20
30
40
12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Menstrual age in weeks

FIGURE 17

Mean abdominal circumference as per menstrual age
Comparison with dhadialla

	THIS STUDY		DHADIALLA	
Menstrual age;weeks	A.C. Mean	Two stddev	A.C. Mean	Two stddev
14	15.2000	0.0000	-	-
15	8.1500	2.9698	-	-
16	11.7500	7.4954	-	-
17	13.7500	1.2806	-	-
18	13.0333	2.1386	-	-
19	14.4667	3.7542	14.3	4.6
20	16.3750	1.3000	14.5	2.0
21	17.2000	6.5230	15.8	2.8
22	17.8100	5.8160	17.0	2.4
23	19.0400	4.8974	17.2	1.9
24	19.8500	4.1348	17.8	2.1
25	19.4769	3.7560	19.9	2.3
26	20.0000	5.1910	20.3	3.0
27	21.4636	5.3764	21.5	2.3
28	24.9875	3.5074	23.1	3.1
29	22.4636	4.9706	23.5	3.2
30	25.5667	6.0086	24.4	4.0
31	26.2368	5.9064	25.4	3.8
32	26.1917	5.3690	26.7	3.0
33	27.5864	4.4662	28.1	3.0
34	27.5579	5.0356	28.4	4.6
35	29.4833	5.4816	30.0	3.2
36	28.8100	4.5430	29.9	4.9
37	29.3385	5.3458	31.8	2.3
38	30.7714	4.9876	32.4	3.4
39	29.6889	4.5194	31.3	7.0
40	30.4500	2.1214	33.3	1.8
41	32.3000	0.0000	-	-
42	29.5000	4.1762	-	-
43	31.0000	0.0000	-	-
44	29.6000	0.0000	-	-

TABLE 7

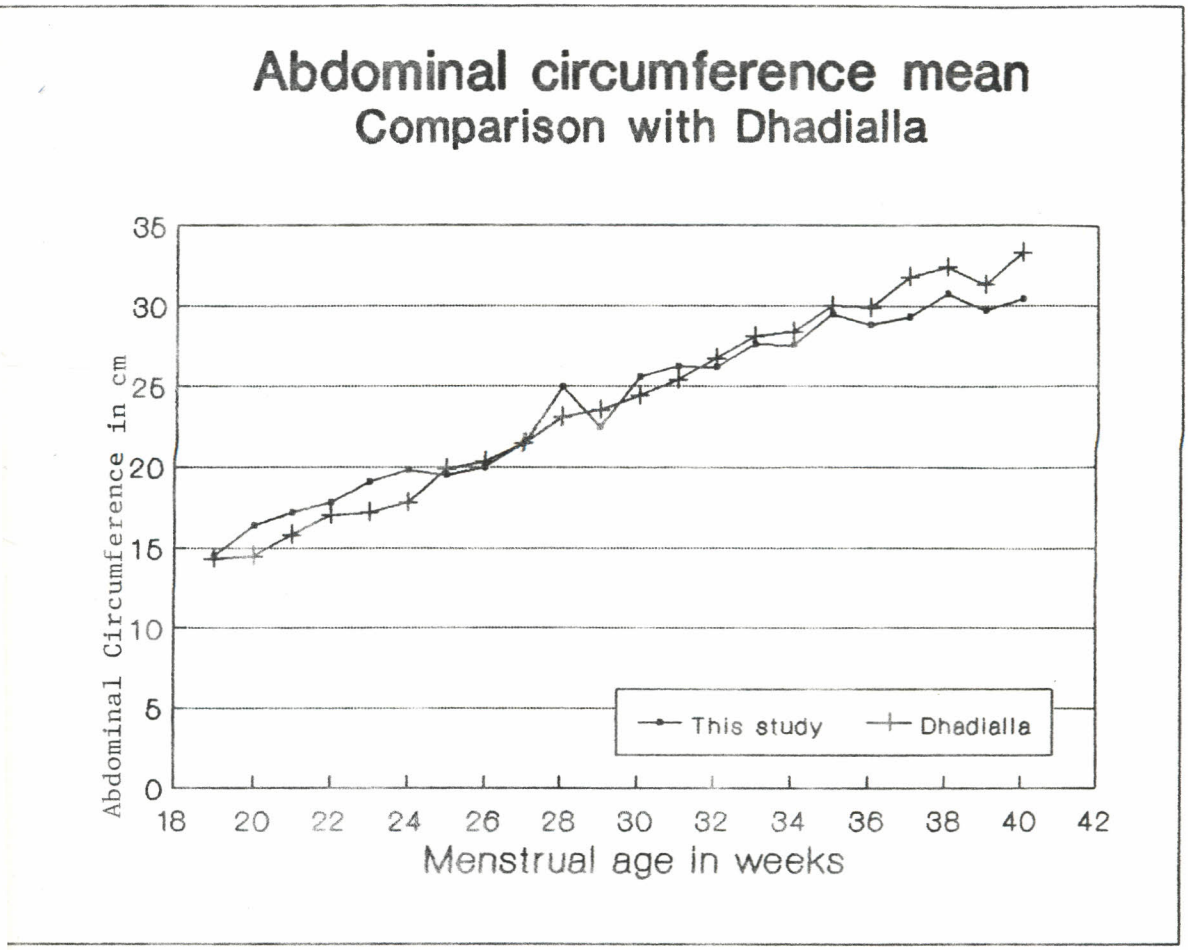

Abdominal circumference mean
Comparison with Dhadialla
Abdominal Circumference in cm
35
30
25
20
15
10
5
0
18
20
22
24
26
28
30
32
34
36
38
40
42
Menstrual age in weeks
This study
Dhadialla

FIGURE 18

Section C:

1. Biparietal Diameter

Biparietal diameter (bpd) was plotted against menstrual age using a non-linear regression formula, bpd cp = a+(bxlmp)+(cxlmp^3), where cp is goodness of fit, or R^2. lmp - menstrual age in weeks.

The computer gave a,b&c values as follows:-

a = -2.41610

b = .40515 and

c = - .00008

289 cases were subjected to mathematical modeling.

Goodness of fit R^2 = 80.381%.

Asymptotic 95% confidence interval curves for lower and upper limits were drawn based on the following computer range:

	LOWER	UPPER
A	-3.4400	-1.3925
B	.3517	.4586
C	- .0001	- .0001

See the asymptotic curve.

2. Head Circumference, hc

The foetal head circumference was plotted against menstrual age using a non-linear regression formula,

hccp3 = a+(bxlmp)+(cxlmp^{3}).

cp3 = head circumference goodness of fit or R^{2}.

a = -8.206445888

b = 1.459264240

c = - .000283233

Asymptotic 95% confidence interval.

LOWER	UPPER
-11.3984	-5.0145
1.2942	1.62434
- .0003	-0.0002

There are 272 cases after removing worst 14 outliers.

Goodness of fit is 84.999%.

See graph.

3. Abdominal Circumference, ac

Formula - compute accp2 = a+(bxlmp)+(cxlmp^3)

Cases available = 281.

cp2 is goodness of fit R^2 - abdominal circumference;

L.M.P. - menstrual age in weeks.

The computer gave the values of a,b,c on statistical package as follows:-

a = -8.30601

b = 1.27789

c = - .00019

Asymptotic 95% confidence interval.

	Lower	Upper
A	-12.3525	-4.2595
B	1.0671	1.4887
C	- 0.0003	- .0001

R^2 = 79.578% - abdominal circumference goodness of fit.

Please see asymptotic curve.

4. Femoral Length, fl

All 284 cases are used. No outliers removed. Subjected to non-linear regression analysis using the formula given as: flcp^2 = a+(bxlmp)+(cxlmp^3) where cp^2 is the value R^2 - Goodness of fit.

Asymptotic 95% confidence interval.

Parameter	Estimate	Lower	Upper
A	-2.6401	-3.5495	-1.7308
B	.3285	.2812	.3759
C	- .0001	- .0001	- .00004

R squared = 1 - Residual ss/corrected ss = 81.366% - Good of fit.
See asymptotic curve

5. Estimating fetal weight in Kg using a formula of bpd, fl and ac as given by Rumach M. Carol et al. (21) and same using only two parameters i.e. femoral length and abdominal circumference are given.
- see graphs.

HEAD, ABDOMEN AND FEMUR

Formula 1:

$$Log_{10}(EFW)=1.4787-0.003343\ AcxFL+0.001837\ BPD^{2}+ 0.0458\ AC+0.158\ FL.$$

ABDOMEN AND FEMUR

FORMULA 2:

$$Log_{10}(EFW)=1.1134+0.05845AC-0.000604AC^{2}- 0.007365BPD^{2}+0.00595BPDxAC+0.1694BPD.$$

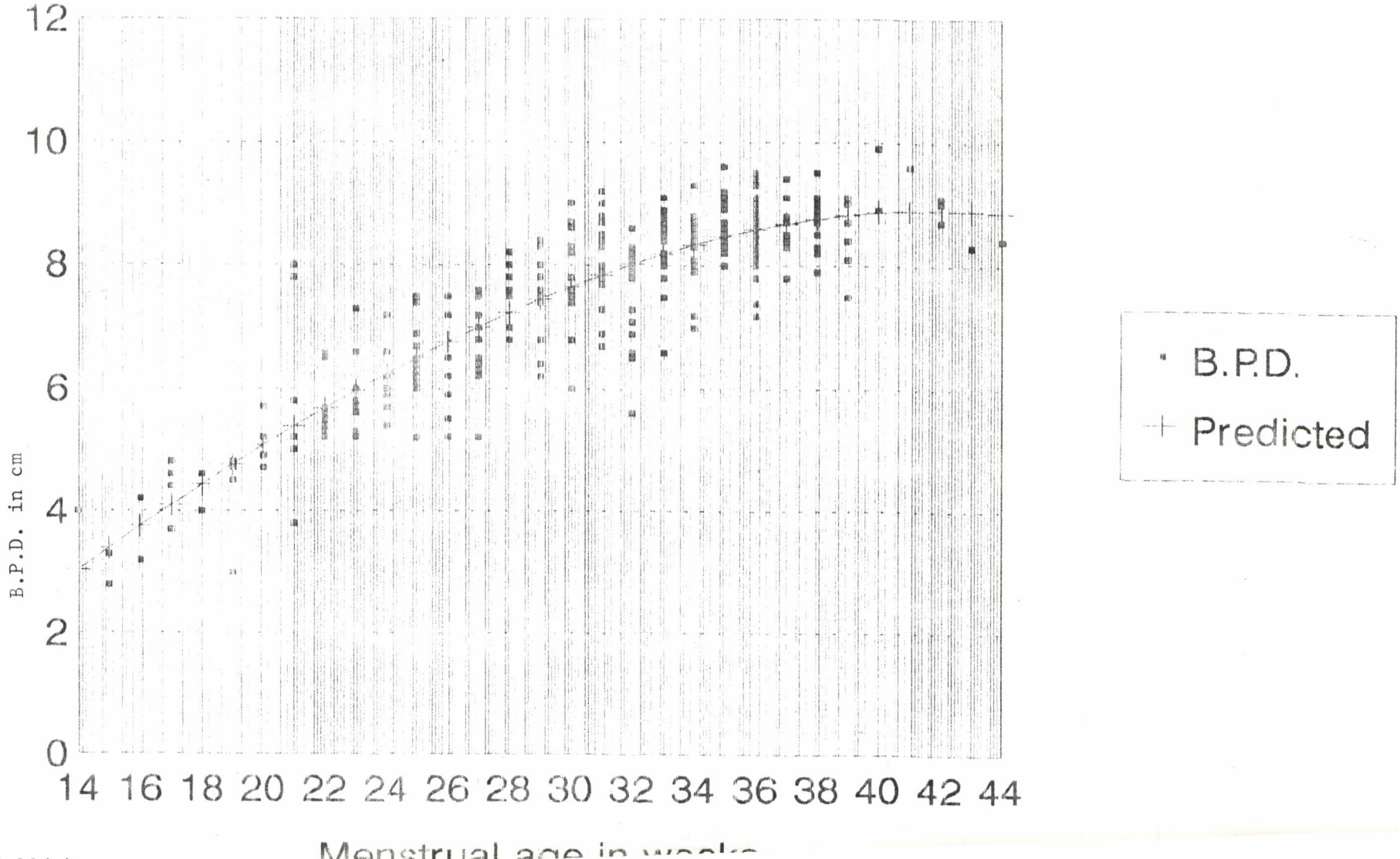

12
10
8
6
4
2
0
B.P.D. in cm
14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Menstrual age in weeks
B.P.D.
Predicted

FIGURE 19(a)

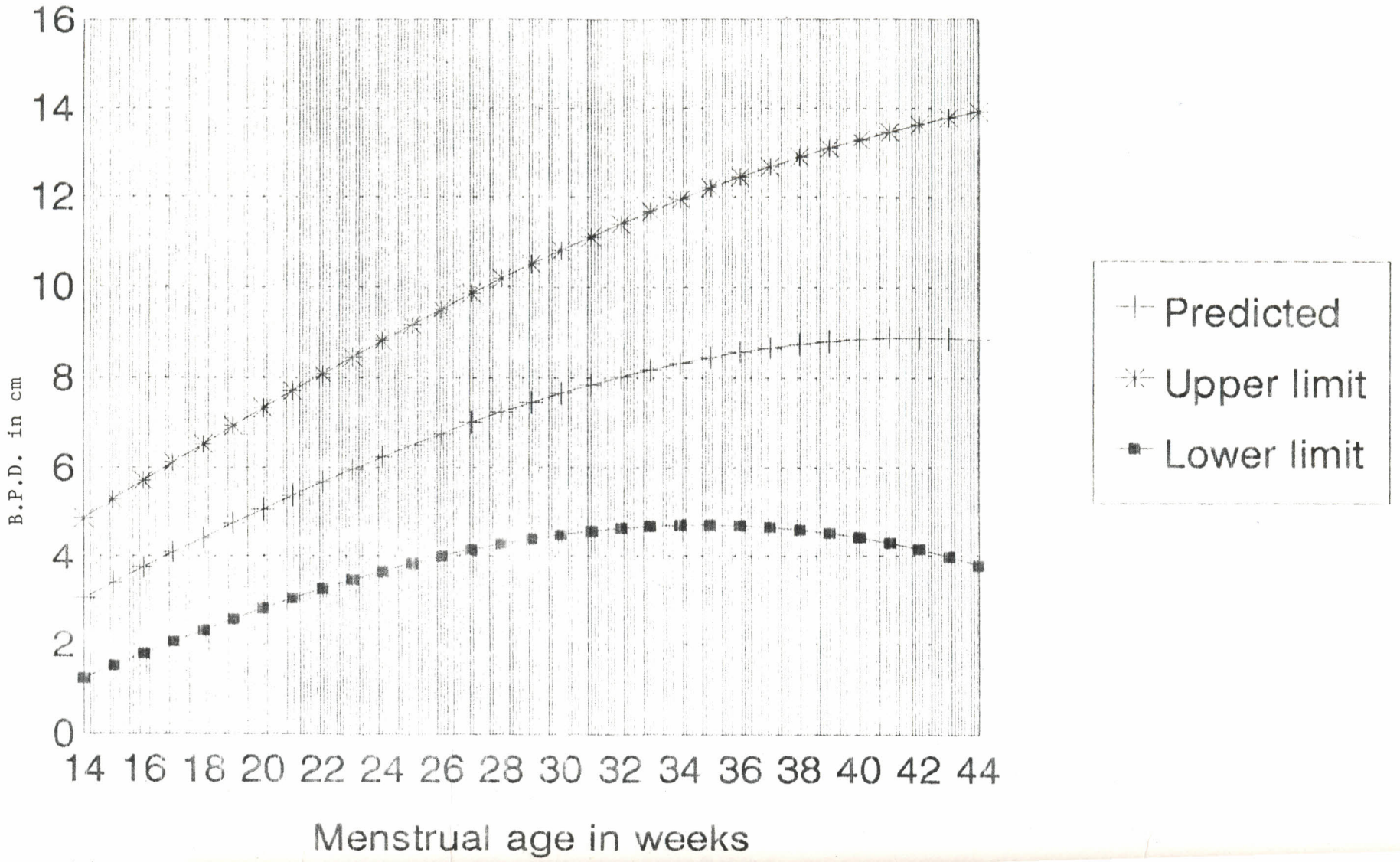

16
14
12
10
8
6
4
2
0
B.P.D. in cm
14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Menstrual age in weeks
Predicted
Upper limit
Lower limit

Figure 19(b)

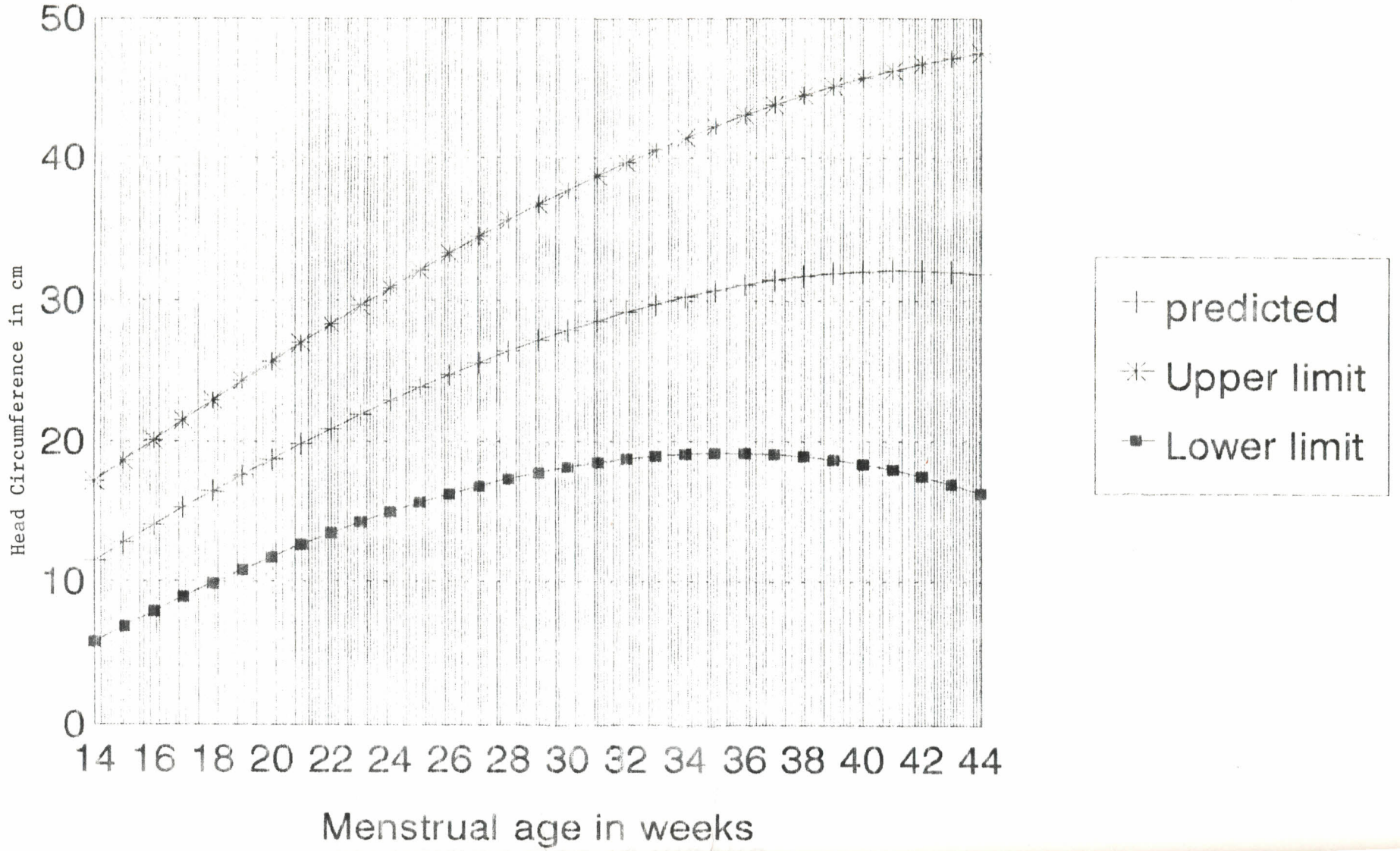
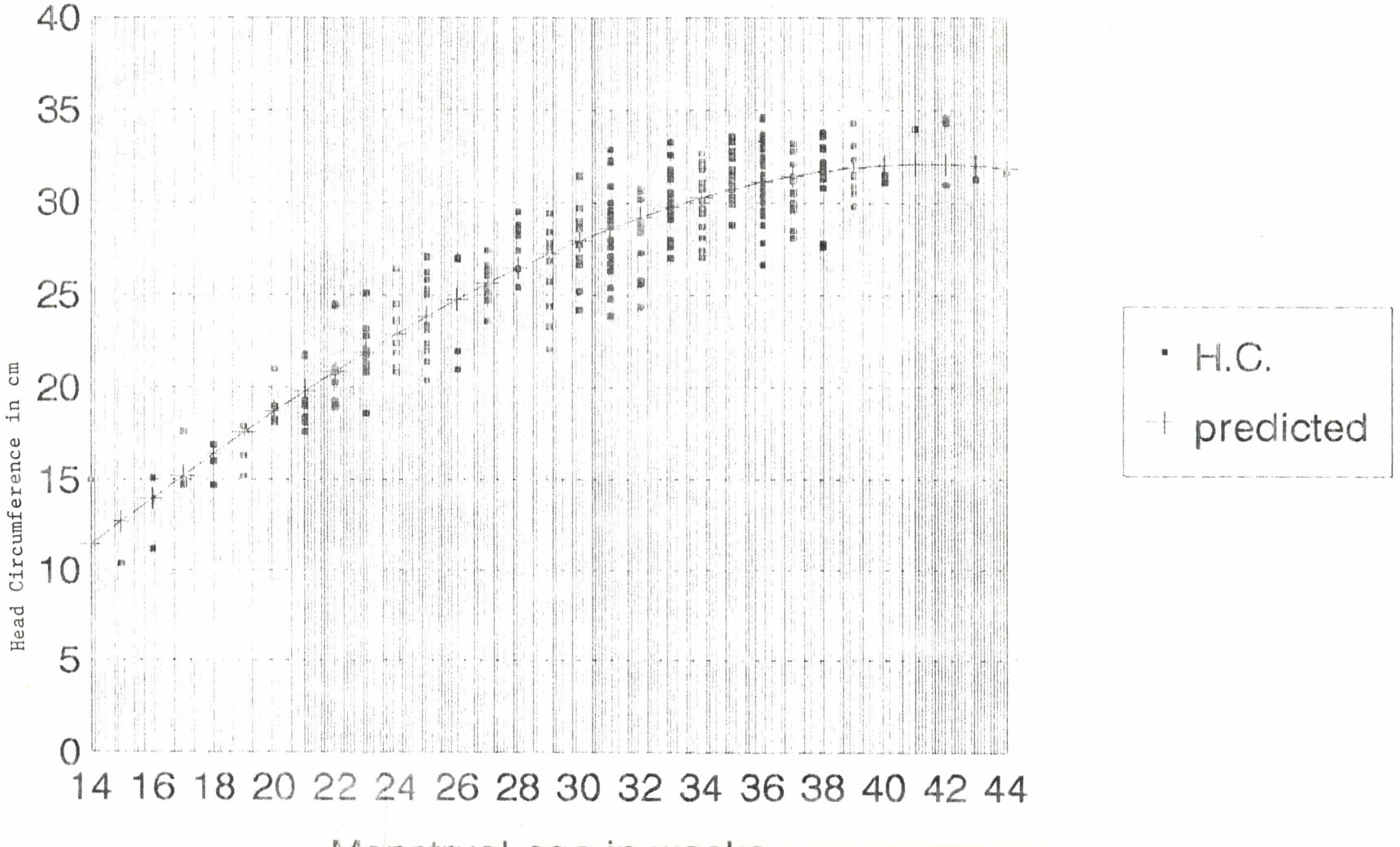

50
40
30
20
10
0
Head Circumference in cm
14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Menstrual age in weeks
predicted
Upper limit
Lower limit

Figure 20(a)


Head Circumference in cm
0
5
10
15
20
25
30
35
40
14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Menstrual age in weeks
H.C.
predicted

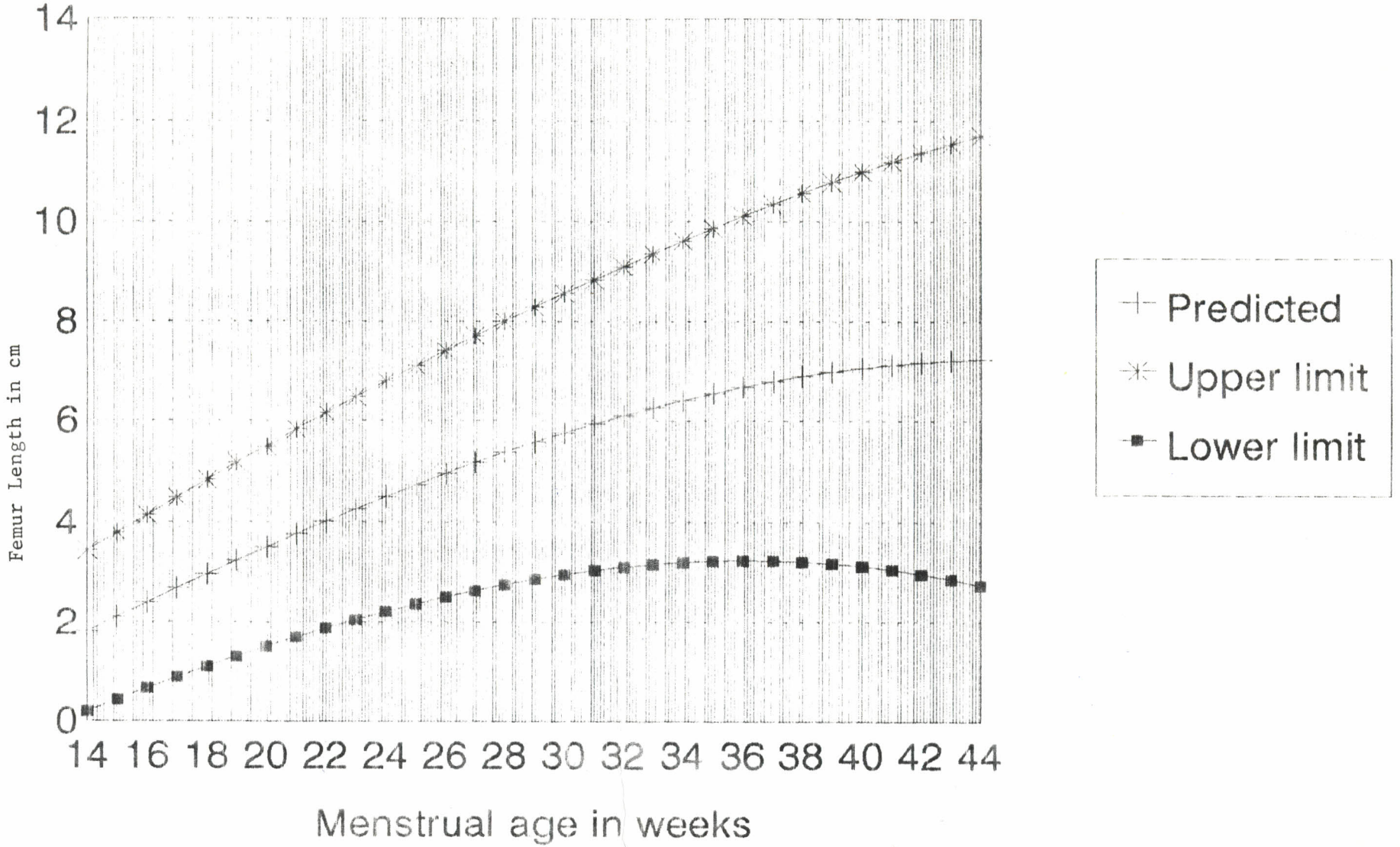


Figure 21(a)

Femur length versus menstrual age

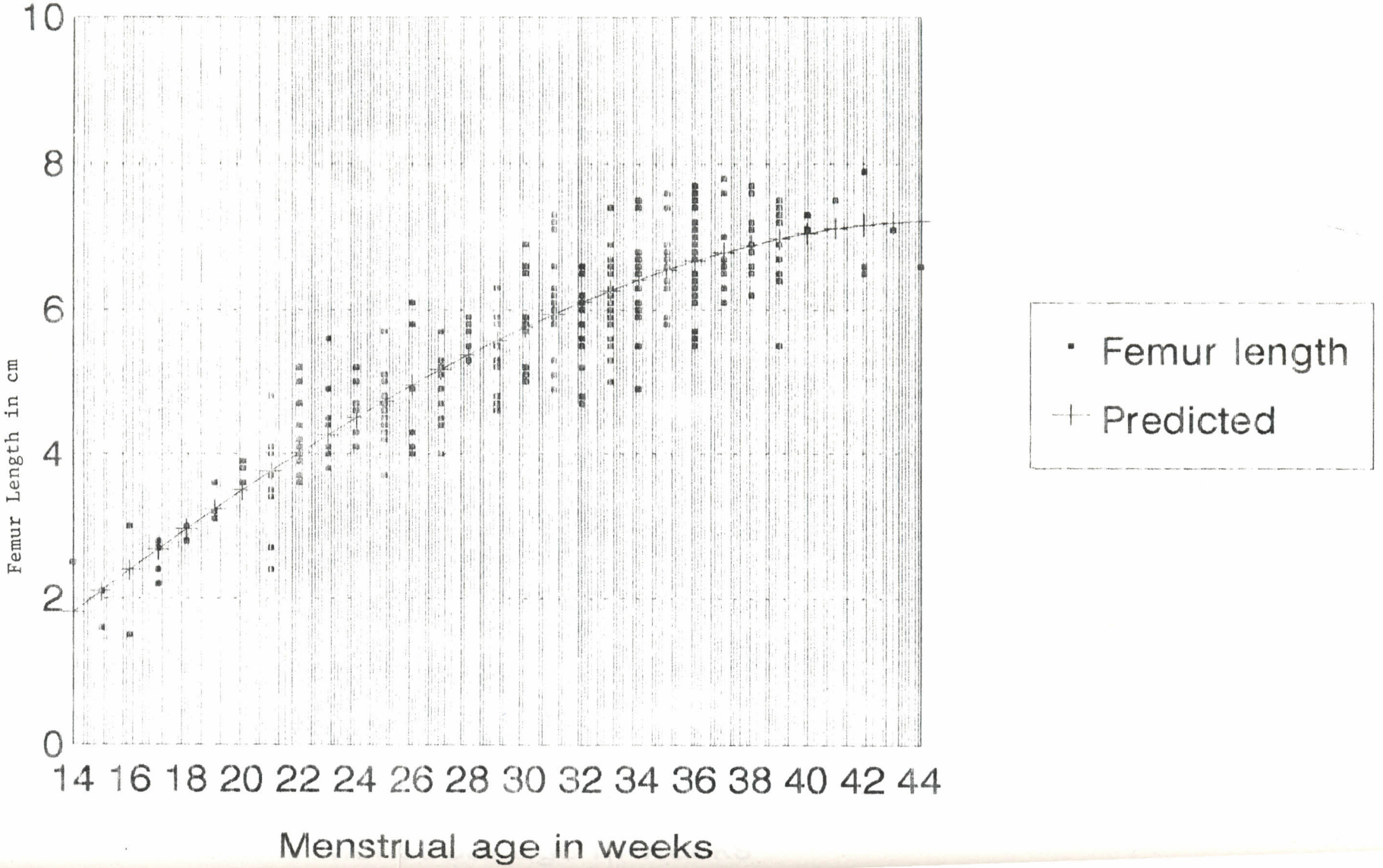

10
8
6
4
2
0
Femur Length in cm
14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Menstrual age in weeks
Femur length
Predicted

Figure 21(b)

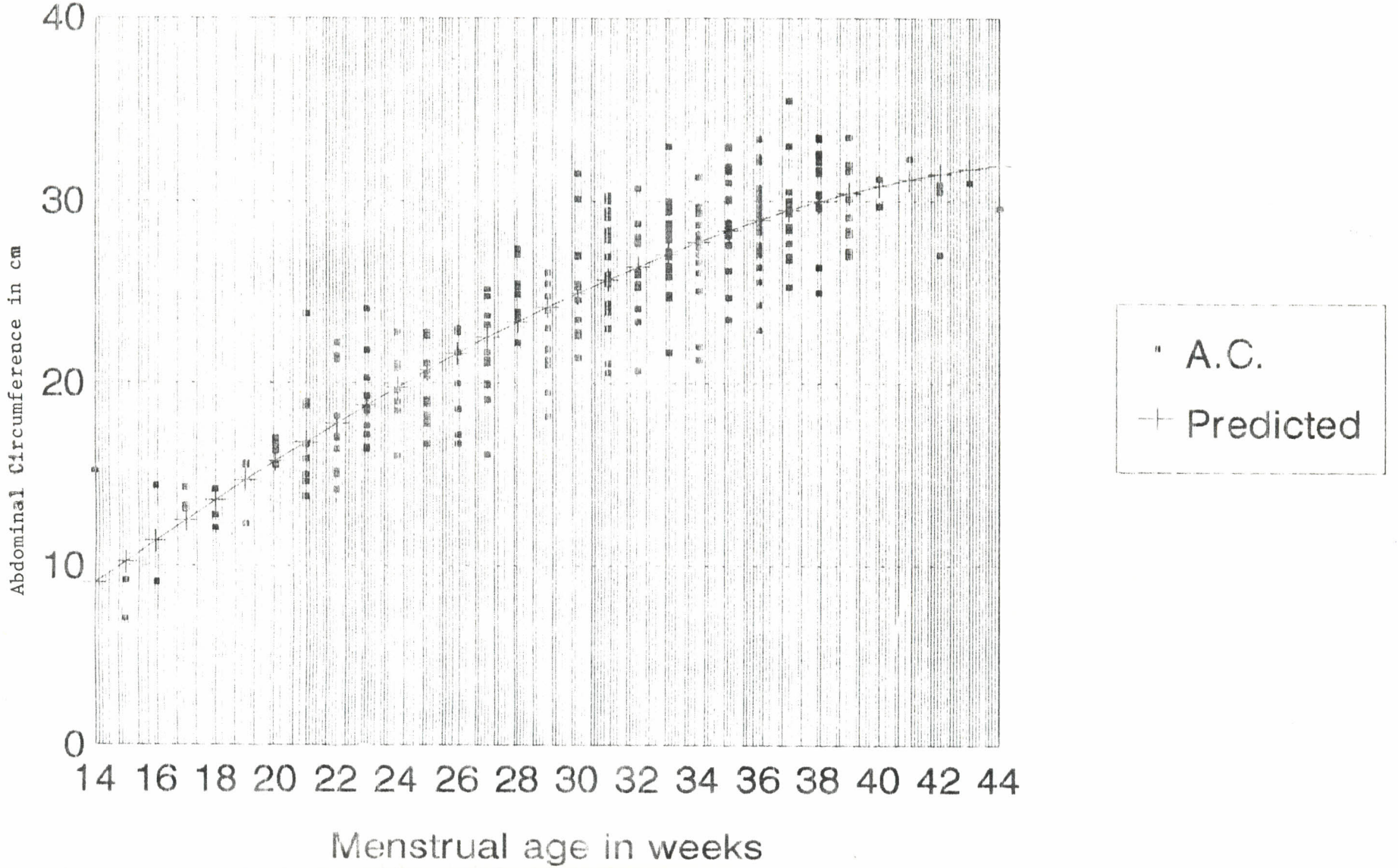

40
30
20
10
0
Abdominal Circumference in cm
14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Menstrual age in weeks
A.C.
Predicted

FIGURE 22(a)

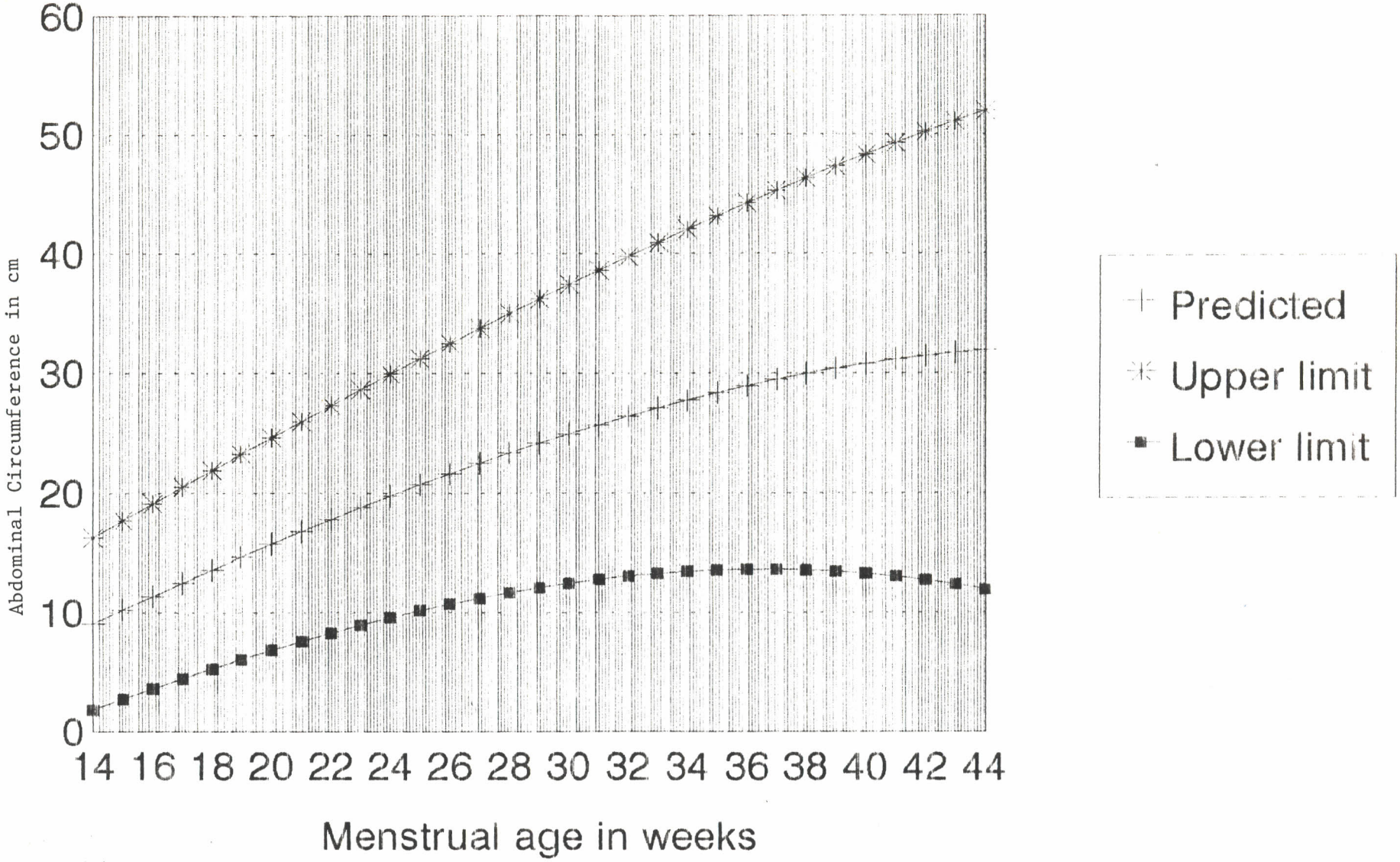
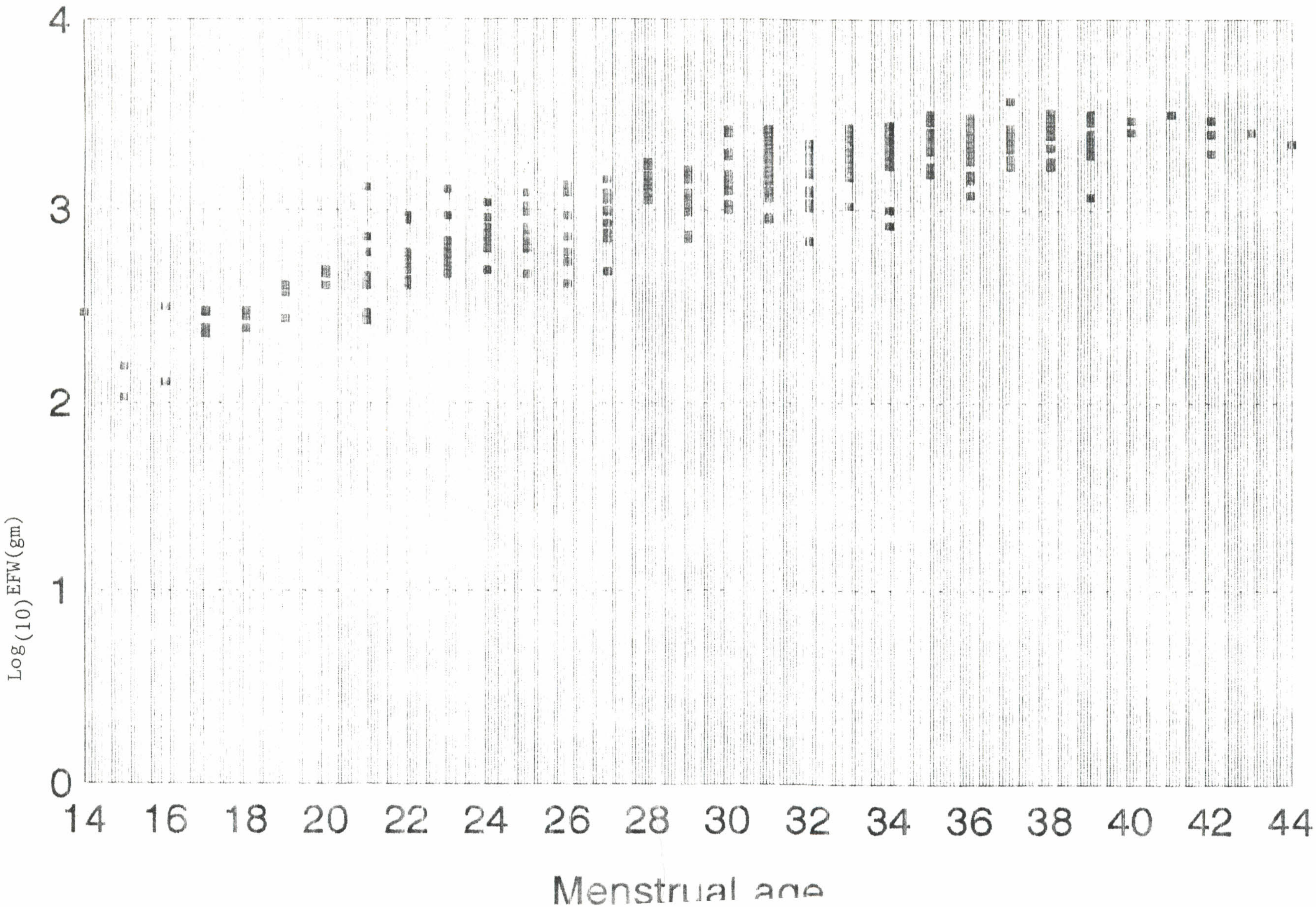

60
50
40
30
20
10
0
Abdominal Circumference in cm
14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Menstrual age in weeks
Predicted
Upper limit
Lower limit

Figure 22(b)



4
3
2
1
0
$Log_{(10)}$EFW(gm)
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
Menstrual age

FIGURE [illegible]

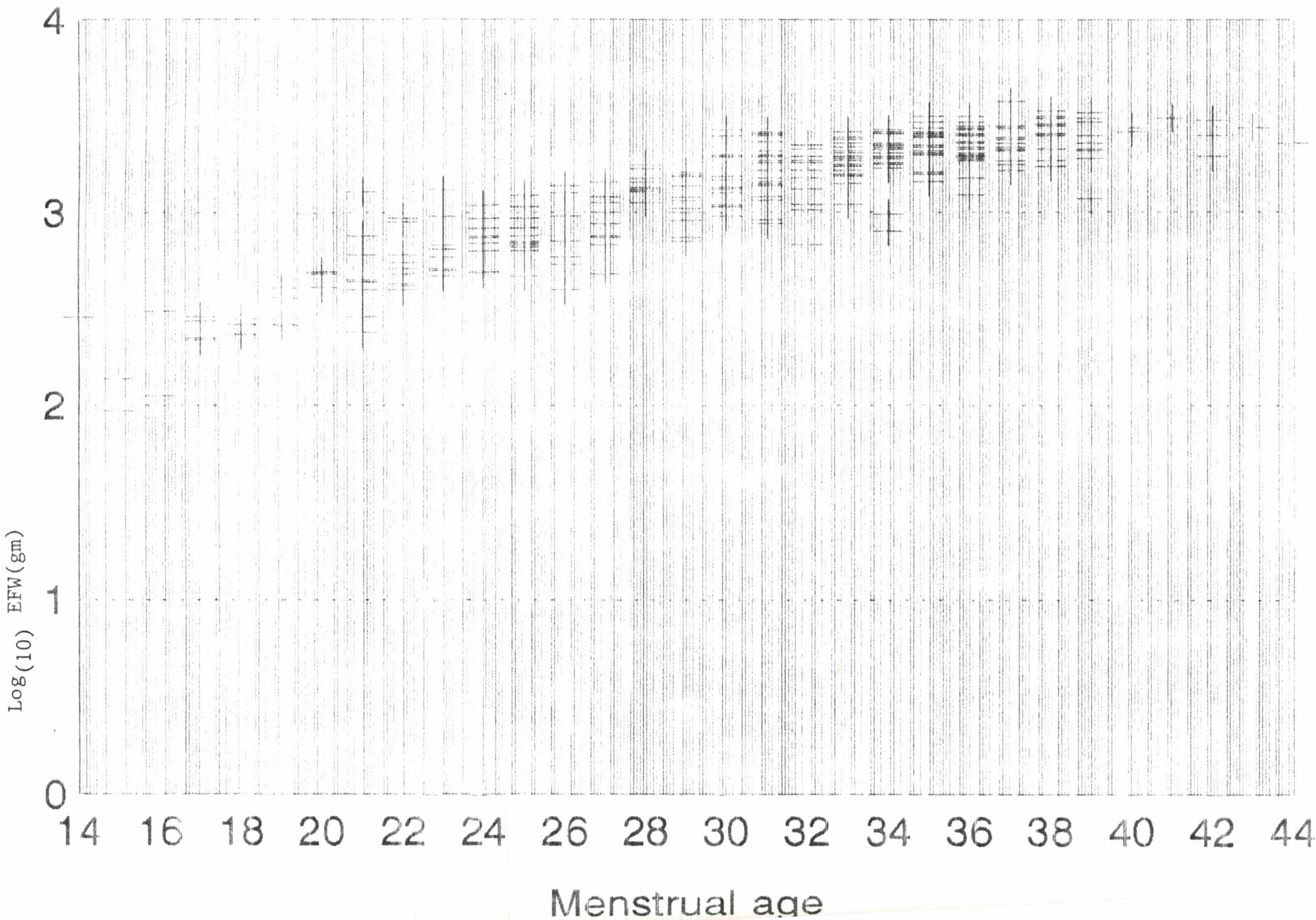
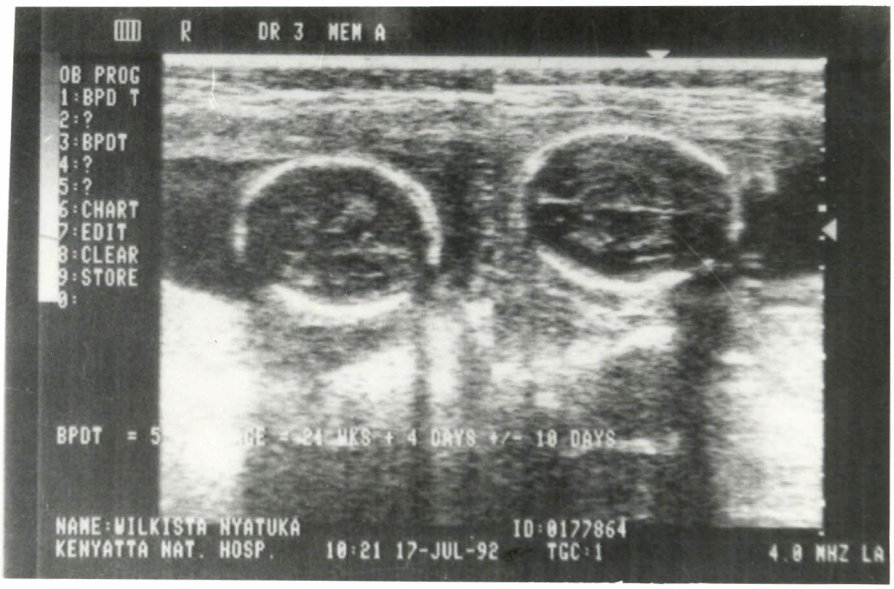

4
3
2
1
0
Log(10) EFW(gm)
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
Menstrual age

FIGURE 23(b)

PLATE 1. BIPARIETAL DIAMETER

KNH.



KEMRI

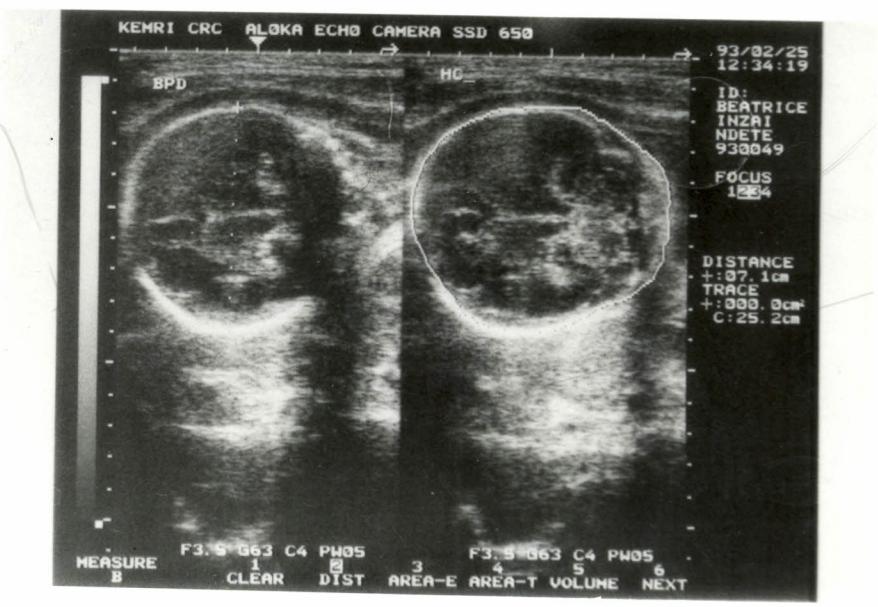
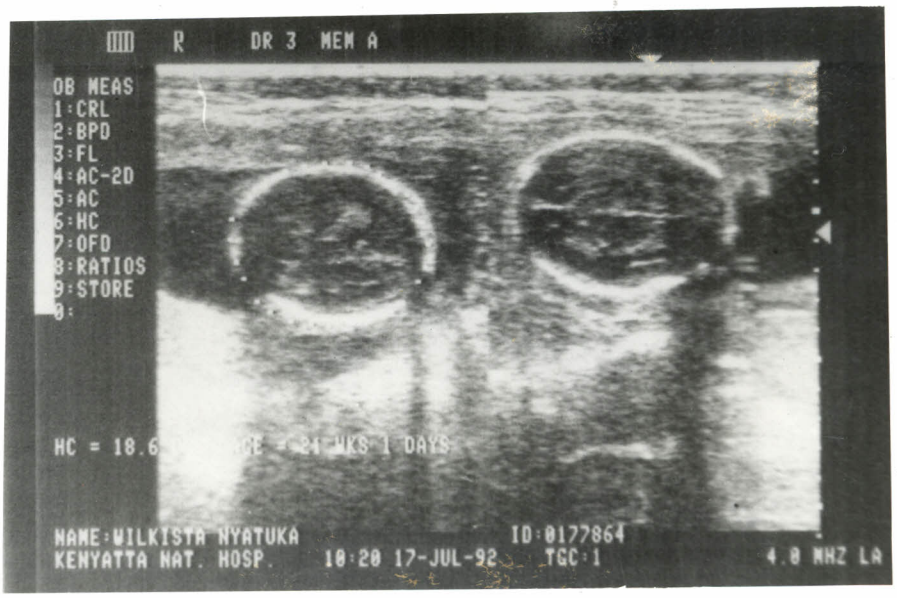


PLATE 2. HEAD CIRCUMFERENCE

KNH.



KEMRI

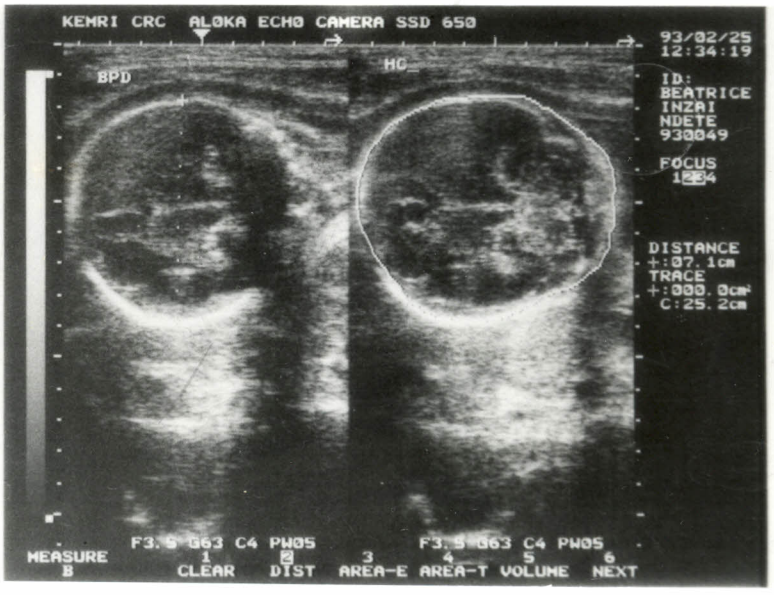
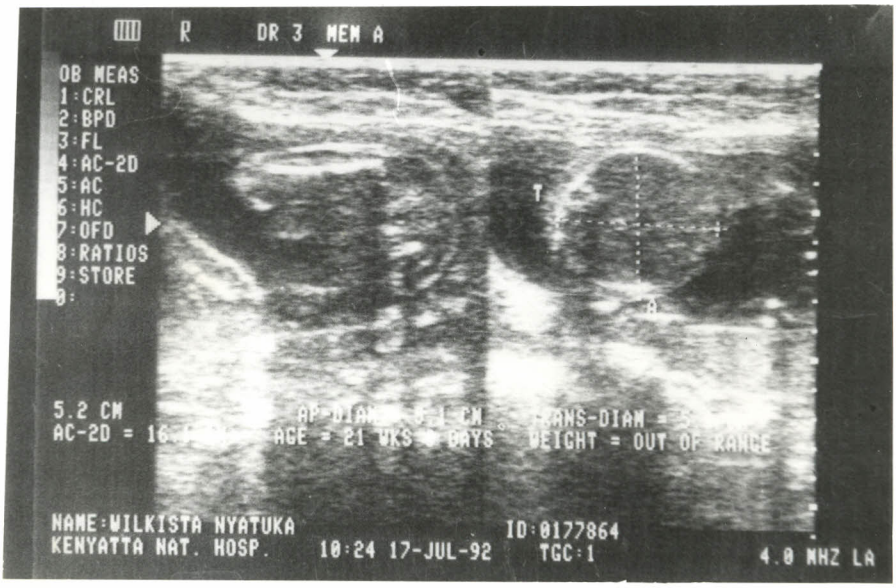


PLATE 3. ABDOMINAL CIRCUMFERENCE

KNH.



KEMRI

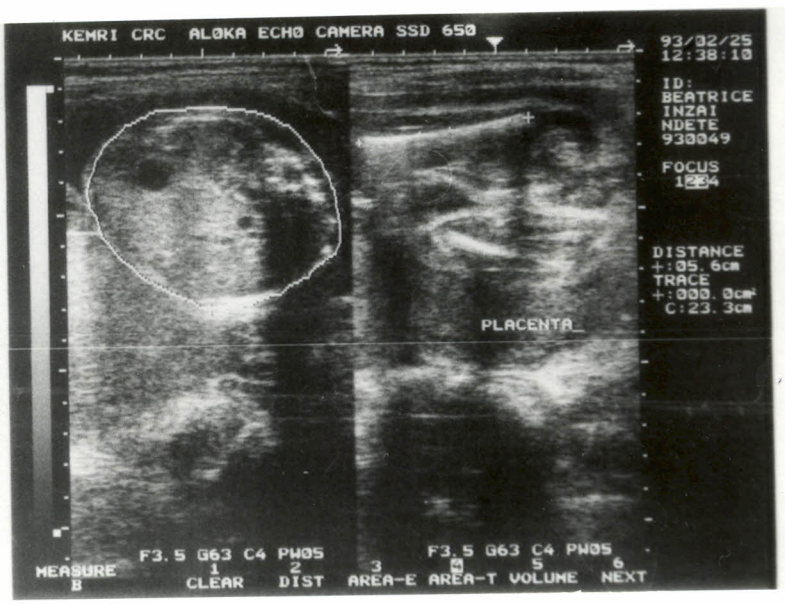
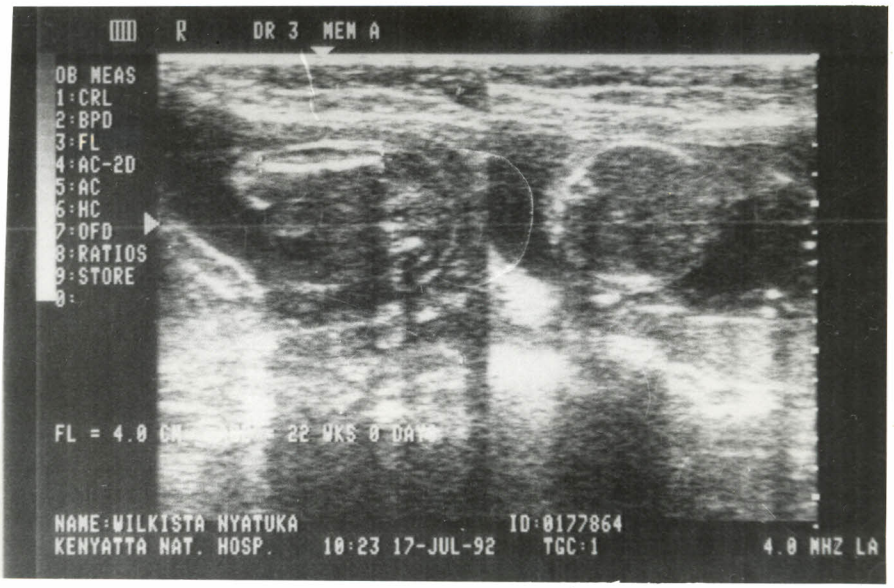
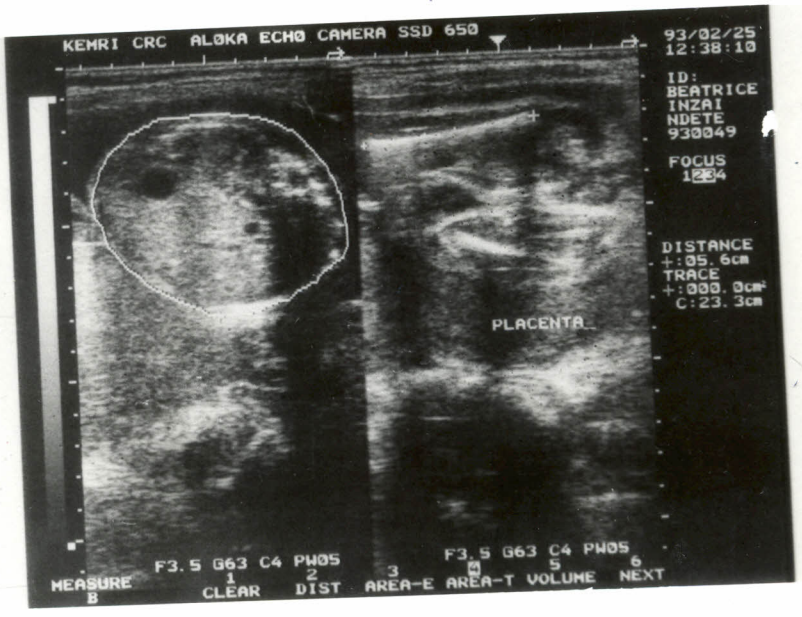


PLATE 4. FEMORAL LENGTH

KNH.



KEMRI



DISCUSSION

Results of the study shown above have been divided into three sections. First are those meant for socio-demographic data and second obstetric measurements divided into means and regression analysis.

Discussion of socio-demographic data is mainly descriptive. The histogram on fig. 1 page 22 gives distribution of patients per age group. Many of the mothers were primigravida. A total of 81.3% of all women were aged 30 or below. There was no clear relationship between maternal age and parity. This seems to have depended on what age someone entered into reproductive family life. For instance a mother aged 26 years had 6 children while one aged 31 had only two.

Marital status showed that the majority are married, i.e. over three hundred while single mothers were about fifty. About half of teenage pregnancies were single. Divorcees, separated and widows were three. It is possible those who did not give their marital status could have added to this number (Histogram Fig.2, page 23).

Histogram Fig.3, page 24 shows distribution according to menstrual age. At presentation for obstetric ultrasonography, many women were in late second and third trimesters. This, however, did not affect menstrual age histograms as in each week of gestation, 12-42 weeks there were at least a patient.

Some women gave menstrual dates that could not be relied upon. For instance one said she was 29 weeks. Measurements on the same patient showed that femoral length, abdominal circumference, head circumference and biparietal diameter were equivalent to 22 weeks. These cases about 14 in all are excluded in statistical analysis, hence outliers.

Monthly income was compounded by flaws. Some of these were:-

1. Reluctance by subjects to tell the truth about their income.
2. Uncertainty about the spouse's income.
3. Irregular cash flow.

Classification into low, middle and high socio-income groups is superfluous with current inflationary trend and dependence (Fig. 4, page 25).

There was a general relationship between parity and age (Figure 5, Page 26). It was noted most mothers had an average of three deliveries between age 25 and 35. This may be explained by economic trend in this country, knowledge attitude and practice of family planning and age at initial conception.

Fetal loss defines high risk groups. Given my sample bias for normal, not many had more than one abortion (Figure 6, page 27).

Placental Position: Only four subjects had placenta praevia.

Of these two were incidental finding at routine ultrasonography. Normal placental position with the highest frequency is an anterior position (Figure 7, page 28).

Section B

A. There were a total of 296 women whose menstrual age was known. The few outliers were removed in statistical analysis.

The extent of analysis to be discussed will be as follows:-

1. Biparietal Diameter

   (a) Among the patients in the study.
   - means
   - regression analysis.

   (b) In comparison with that of Osefo, Rogo and Yagel et al (1986).

   (c) Contribution by Kurtz A.B. (14) is noted.

   (d) Limitations.

2. Head Circumference

   (a) Valid obstetric population.
   - Means
   - Regression analysis

   (b) Comparison with Frank P. Hadlock, AJR 138:649, 1982).(15)

(c) Head circumference to abdominal circumference ratio.

(d) Limitations.

3. Abdominal Circumference

(a) Valid obstetric cases.

- Means
- Regression analysis

(b) Comparison with that of Dhadialla (1986)(9) and Hadlock F.P. et al. (19)

(c) Abdominal circumference for fetal weight estimation.

(d) Limitations.

4. Femoral Length

(a) Valid obstetric cases.

- Means
- Regression analysis

(b) Comparison with Qureshi, 1989 (10), and Yagel et al (1986) (33). Contributions by Jeanty P.J., Ultrasound Med.3:75, 1984 is mentioned.

Gestation adjusted growth rate, gestation age range in weeks versus variability (weeks) at 95% confidence limit, gestation age at delivery birth weight estimation were not done; neither is calculation of multiple fetal age assessment parameters versus single parameters.

B. Biparietal Diameter

Assumption made in this and the following subsection is that sonographers followed correctly the methodology outlined. Instances of difficult measurements of foetal biparietal diameter occurred with the foetal head deep in the pelvis of the mother, occipito posterior, breech and near term gestation. With patience and palpation usually the foetus moved. This permitted axial sonography putting biparietal eminences, basal ganglia and thalamus in the same plane parallel to base of skull. Occasionally a large foetal head had to be measured adequately by means of a sector transducer. This was rare and far in between.

In the table of means shown there is uniform increase in b.p.d measurements second trimester which become non-uniform in the third. This is explained by differential foetal growth that is a normal phenomenon in pregnancy. The table of means of this study compared to Osefo, Rogo, Yagel et al (1986) show good correlation (7,12,33).

Within 95% confidence limit, two standard deviation, my predicted means significantly from those of Kurtz. Biparietal diameter at term often exceed 9.2cm - with 9.6cm at upper limit (not demonstrated).

The results of biparietal diameter were subjected to linear cubic, (R^2) regression analysis. A graph showing biparietal diameter versus menstrual age was drawn. Range of values within two standard deviation are shown. An asymptotic curve was obtained. Goodness of fit of 80.381% compares with advanced centres (e.g. Hadlock et al)(4).

Limitations:

These were:-

(i) failure to get equal number of patients in each gestation age bracket.

(ii) possibility of inter-observer error.

(iii) Non-standardization for the head shape using cephalic index.

(iv) Fetal variation in head size depending on maternal size, health, gestational age and fetal development.

(v) Small numbers at each of very early second and late third trimesters.

C. Head Circumference

Valid number of subjects tested is 272. Given this measurement takes into consideration head shape and occipito frontal diameter, it is more reliable in case a fetus was either dolichocephalic or brachycephalic. (Campbell S. et al, Hadlock et al, Sabbagha and Callen Peter) (3,4,8,38).

The formula given in methodology for linear cubic regression was used. This gave a higher correlation compared to linear quadratic.

The goodness of fit was found to be 84% as compared to 78% in linear quadratic. An asymptotic 95% confidence interval curve created for mean head circumference versus menstrual age is similar to that of Hadlock F.P. et al., Yagen et al.

Relationship between head circumference and abdominal circumference is useful in studying asymmetric growth

retardation. Ratio of head circumference divided by abdominal circumference versus gestation age showed a reduction from 1.15 at 15-16 weeks gestation to 0.90 at 41-42 weeks. This generally indicates head to abdomen foetal symmetry.

Limitations:

(i) Being not one of the commonly assessed parameters at Kenyatta National Hospital, there was a tendency to forget to take head circumference at the inception weeks of the study.

(ii) Tracer technique tended to extrapolate areas of the head which would not fit on cathode ray oscilloscope ultrasonography screen.

(iii) Means were in a few cases impossible as only a patient appeared on a certain age bracket.

(iv) Table of head to abdominal circumference is excluded to reduce large number of tabulations.

D. Abdominal Circumference (A.C.)

Fetal age assessment by abdominal circumference is estimated from 14 weeks to 44 weeks. 281 cases were studied.

There is greater variations of AC measurements with wider standard deviations for menstrual age compared to femoral length and biparietal diameter. The rate of increase in abdominal circumference in the last 4 weeks of third trimester is more rapid than head circumference measurements.

Mean abdominal circumference for menstrual age in this

study compares well with that of Dhadialla in Aga Khan 1986. The table of foetal parameters versus menstrual age from 19 to 40 weeks shows lower measurements in this study. It is a result of fewer measurements at each completed week.

Linear cubic regression analysis of this study gave goodness of fit of 79.578%. The scatter diagram drawn was similar to that of Hadlock F.P. et al(19).

Limitations.

1. An obvious under estimation of AC after 35 weeks is noted. This might be explained by inter observer errors.
2. Level of abdominal girth measured depended on the observer visualisation of portal vein and stomach.

Weight estimation of foetuses at different menstrual ages were taken. Two formulae were used (Rumack C.M. et al. 1991 (21), Chapter 34- pp 728-731) i.e 1 + 2 given below..

Key to abbreviations used:-

EFW - Estimated Foetal Weight in gm.

BPD - Biparietal Diameter in cm.

AC - Abdominal Circumference in cm.

FL - Femur Length in cm.

Formula 1

$$\log_{10}(EFW) = 1.4787 - 0.003343\ AC \times FL + 0.001837\ BPD^2 + 0.0458\ AC + 0.158\ FL.$$

Formula 2

$$\log_{10}(EFW) = 1.1134 + 0.05845\ AC - 0.000604\ AC^2 - 0.007365\ BPD^2 + 0.00595\ BPD \times AC + 0.1694\ BPD.$$

The estimated foetal weight using the formula given for menstrual age gave a graph similar to relevant studies done elsewhere. No attempt is made to compare with birth weights since records of the women who delivered in Kenyatta Hospital was a small percentage of the total studied.

Limitation: All mothers admitted to Labour Ward were issued unit file numbers. Since this study records were based on antenatal clinic numbers, it was not possible in absence of this to procure many dates of delivery.

Femur Length

Measurements were consistent. Rate of increase of femoral length was uniform till approximately 35 weeks of menstrual age. 284 cases were studied. Regression line with 95% confidence limits drawn for menstrual age was almost linear. In linear cubic regression analysis the goodness of fit was found to be 81.366%. This was higher than linear quadratic which was 75%.

Similar studies have been done. Locally Qureshi Z.P. in 1989 found that the femur length was not a better predictor of menstrual age compared to biparietal diameter. O'brien D.G. et al 1981, Ye Ming-Neng et al 1982, Poll V. et al.(16,20,34) all show high correlation on linear quadratic and cubic equations.

Results shown by Dr. Quresh give similarity to means in this study.

From this study at Kenyatta National Hospital, it would appear femoral length was very consistent. It gives a uniform menstrual age estimation even in late third trimester.

Limitations:

1. The lower limb being mobile compared to the rest of the body it required patience on the part of the investigator to measure correctly. Due to limited study duration per patient all femur lengths measured were sometimes not portrayed in their longest plane.

CONCLUSIONS

The population under study was drawn among those who normally visit antenatal clinic at Kenyatta National Hospital. This is not entirely representative of the city where over 90% of pregnant women are delivered, among other institutions at Nairobi Hospital, Aga Khan, Pumwani Maternity, Jamaa Maternity and Nursing Home. In a nut-shell the very normal population deliver in private, high cost institutions or free City Council maternity health centres such as Langata, Eastleigh, Kariobangi, Westlands and Jericho.

Marriage in this country, in essence, is simplified by common agreement among partners to make spouses. Hence the majority were married. Low parity among this study population reflects their youthful age. No conclusion is to be drawn from foetal loss because in normal pregnancy which is well managed no foetal loss is anticipated. Placental position compares with other centres (Kukard et al 1973 (22).

The study of multiple fetal age assessment parameters shows that:

(1) Biparietal diameter is the most frequently studied and gives high accuracy from 16-28 weeks of gestation.

(2) Femoral length sonography gives a linear graph and high positive correlation even in third trimester of pregnancy.

(3) Head circumference is more useful than biparietal diameter in estimating gestation age in third trimester.

(4) Head circumference/fetal abdominal circumference ratios describe fetal symmetry.

(5) Besides abdominal circumference being a reliable indicator, it with BPD or FL or single can give estimated foetal weights. Some of the formulae used were shown earlier.

(6) Linear cubic regression analysis is a better study compared with linear quadratic e.g which gave a maximum correlation of 75% for biparietal diameter.

(7) Phillips Orion and Aloka, SSD 650 ultrasonography machines with linear transducers 4MHz, 3.5 MHz respectively are of high quality and reliability.

RECOMMENDATIONS

- Multi-departmental collaborative study between department of Obstetrics and Gynaecology, Medical Statistics and Sonologistics to be undertaken in the near future.
- Need for a separate ultrasound machine for ample time to carry out relevant research projects.
- Representation in good numbers of normal pregnant women at each gestation weeks from 12-40 weeks.
- Stricter control on inclusion/exclusion criteria; achievable by accurate history taking, physical examination and ancillary laboratory tests.
- Study to be done in two to three years so that those who deliver can have their weights related to individual and multiple growth parameters.
- Records to include antenatal clinic numbers so that one can retrieve records when patients deliver. The situation today, where patients who deliver get a totally new unit number negates follow up of the records. Hence birth weights and dates of delivery were not availed in this study.
- Funds be set aside to pay for study patients, at least in part as many came and could not pay.

ACKNOWLEDGEMENTS.

1. I wish to thank Dr. J.M. Kitonyi and Professor S.B.O. Ojwang. Their patience, diligent suggestions and corrections were, are and will be ever more a glowing foresight to me. I feel privileged by this support.
2. My acknowledgements also go to the Chairman, Radiology Department, Dr. Onyango-Akena, Director, Clinical Research Centre of Kemri Dr. Gachihi S. They were so kind in granting me space to use the ultrasonography machines.
3. To the technologists here in Kenyatta National Hospital and at Kemri who took my job into theirs.
4. To Bill Oyieke for mobilising sources of obstetric patients from the antenatal clinic; a big thank you.
5. I wish to thank Mr. Lambert Nyabola, M.Sc. Lecturer Biostatistics in reading and sorting out this data statistically.
6. To Dr. Wanene who created all those graphs, feeding, controlling and delivering processed computer products neatly arranged.
7. To Deborah Sirima and Janet Musia; their secretarial acumen typed into good reading my otherwise illegible handwriting.
8. I thank my family dearly. They are my wife Agnes and children Yvonne, Yvette and Francis, who were patient with me during my study and write up of this dissertation.
9. Finally I acknowledge all the referred authority.

APPENDIX I

DATA COLLECTION SHEET

Date.....

Case No.:.....

Name..... Reg. No.....

Address: Clinic No..... Parity.....

Ward.....

Other.....

Age.....

Marital status: 1 Married 2 Single
3 Separated or Divorced

Income per month 0 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 10000

L.M.P. EGA by L.M.P.

Special reasons for ultrasound
..... Dates by this.....
.....
History..... Living.....
No. of fetuses..... Fluid.....
Fetal position.....
Placenta location.....

MEASUREMENTS

		Range	
B.P.D.	-	Weeks	Percentile
H.C.	-	Weeks	Percentile
F.L.	-	Weeks	Percentile
A.C.	-	Weeks	Percentile

EGA by L.M.P.....

EGA by prior U/S.....

EGA by measurements.....

INVESTIGATOR.....

RESIDENT DOCTOR.....

SUPERVISOR.....

APPENDIX II

OBSTETRIC ULTRASONOGRAPHY PATIENTS

TITLE OF FIGURE

APPENDIX III

LIST OF GRAPHS

APPENDIX IV

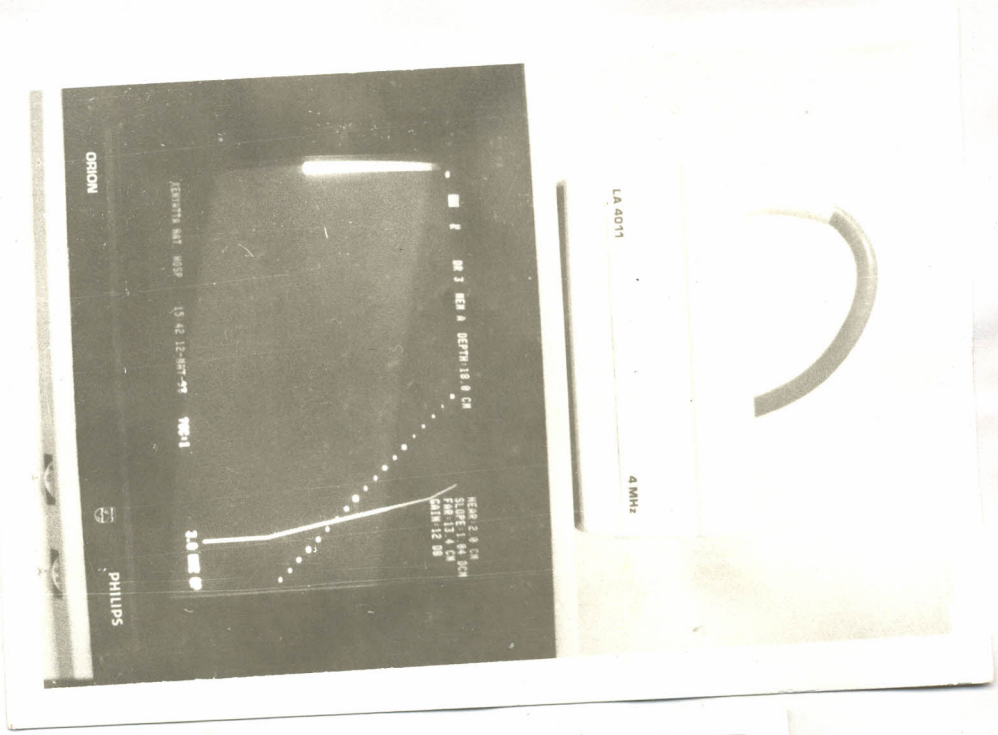
TABLES

GRAPHS

APPENDIX V

ULTRASONOGRAPHY MACHINES

PHILLIPS ORION
KNH.



SSD 650 ALOKA
KEMRI

REFERENCES

1. Donald I., Macricar J., Brown T.G. - Investigation of abdominal masses by pulsed ultrasound. Lancet 1:1188, 1958.

2. Diagnostic Ultrasound Imaging in Pregnancy. Report of a consensus development conference sponsored by the National Institute of Child Health and Human Development. February 6-8, 1984, Bethesda, Maryland, NIH Publication No. 84-667.

3. Campbell, Stuart, Steven L. Warsof, David Little and Derek J. Cooper - Routine Ultrasound Screening for the Prediction of Gestational Age. (Journal, **Obstet. Gynecology** 78:513-519, 1985).

4. Hadlock P. Frank, Ronald B. Harrist, Yogeah P. Shah, David E. King, Seung K. Park and Ralph S. Sharman - Estimating Fetal Age: using Multiple Parameters. A prospective Evaluation in a Racially Mixed Population. (Am. **J. Obstet. Gynecol.** 1987; 156:955-7).

5. Campbell S. An improved method of fetal cephalometry by ultrasound (**J. Obstet. Gynecol.** British Commonwealth 75:568, 1968).

6. Hadlock P. Frank, Russel L. Deter, Ronald B. Harrist and Seung K. Park - Fetal Biparietal Diameter.

   Rational choice of plane of section for sonographic measurements. **American Journal of Radiology (A.J.R.)** 138:871-874, may 1982.

7. Rogo Khama, Mati J.K.G. and Prigg S.M.M. *Preliminary experience with B mode ultrasonography.* Normal fetal biparietal diameter measurements in black Kenyan women. (**J. Obst. Gyn. East Central Africa** 3:2, 1984).

8. Sabbagha, E. Rudy, J. Howard Turner, Howard Rochette, Julius Mazer, and Julie Orgill - Sonar B.P.D. and fetal age. Definition of the relationship. (Department of Obstetrics/gynaecology, **Pittsburgh School of Medicine, Magee - Women's Hospital**, Vol.43, Nol.1 - Jan. 1974).

9. Dhadialla S. Harmeet - Biparietal Diameter and Fetal weight Nomogram by ultrasonography of middle class African and Asian women in Nairobi. (A dissertation for Master of Medicine degree course in Obstetrics and Gynaecology at the **University of Nairobi in 1986).**

10. Quresh Z.P. - *Ultrasonic Fetal Femur length* measurement for Gestational age assessment. Its relation to Biparietal Diameter. (Master of Medicine dissertation - **University of Nairobi, 1989** - Department of Obstetrics and Gynaecology).

11. Sabbagha, E. Rudy and Howard Turner - Methodology of B-scan sonocephalometry with Electronic Calipers and correlation with Fetal Birth Weight. (Obstet. Gynecol. Pittsburgh School of Medicine, **Magee Women's Hospital, Pittsburgh** pa 15213 - Jan. 31, 1972).

12. Osefo N.J. and Chukudebelu W.O. - Sona Cephalometry and Fetal Age relationship in the Nigerian Women. (**East African Medical Journal** Vol. 60, No.2, February 1983).

13. Doubilet M. Peter, Robert A. Greens - Improved Prediction of Gestational Age from Fetal Head Measurements. (**American Journal of Radiology 142:797-800**, April 1984).

14. Kurtz A.B., Wapner R.J., Kurtz R.J. et al. Accurate analysis of Biparietal Diameter as an indicator of gestational age. (**Journal of Clinical Ultrasound 8:319**, 1980).

15. Hadlock P. Frank, Russell L. Deter, Ronald B. *Harrist and Seung K. Park* - Fetal Head Circumference: Relation to Menstrual Age (**A.J.R.** 138:649-653 April 1982).

16. O'brien D. Gregory, John T. Queenan and Stuart *Campbell - Assessment of Gestational Age in the second trimester* by real-time ultrasound measurement of the femur length. **Am. J. Obstetrics gynaecology** 139:540, 1981.

7. O'Brien D. Gregory and John T. Queenan - Growth of the Ultrasound Fetal Femur Length during normal pregnancy.

(American Journal of Obstetrics Gynaecology 141:833, 1981).

18. Hadlock P. Frank, Ronald B. Harrist, Russell L. Deter and Seung K. Park - Fetal Femur Length as a Predictor of Menstrual Age: Sonographically measured (**AJR** 138: 875-878, May 1982).

19. Hadlock P. Frank, Russell L. Deter, Ronald B. Harrist and Seung K. Park - Fetal Abdominal Circumference as a Predictor of Menstrual Age. (**AJR** 139:367-370, August 1982).

20. Poll V. and Kasby C.B. - An improved method of fetal weight estimation using ultrasound measurements of fetal abdominal circumference. (**British Journal of Obstetrics and gynaecology**, December 1979, Vol. 86 pp 922-928).

21. Rumack C.M., Stephanie R. Wilson and Charbonean, J. William -Diagnostic ultrasound 1991 Chapter 34 pp 728-731. Published by MOSBY year book.

22. Kukard R.F.P. and M.E. Freeman - The Clinical Application of Ultrasonic Placentography. (**Journal of Obstetrics and Gynaecology of the British Commonwealth**, May 1973 - Vol.80 pp.433-437)

23. Campbell S. - The prediction of fetal maturity by ultrasonic measurement of the Biparietal Diameter. **J. Obstetrics gynecology - British Commonwealth** 75:603, 1969.

24. Johnson M.L., Dunne M.G., Mack L.A., Rashblury - Evaluation of fetal intracranial anatomy by static and real time ultrasound. (**JCV** 1980:8;311-318).

25. Hadlock P. Frank, Russell L. Deter, Ronald B. Harrist and Seung K. Park - Estimating fetal age. Computer assisted analysis of multiple fetal growth parameters. **Journal of Radiology 1984:** 152:497-501.

26. Hadlock P. Frank, Ronald B. Harrist, Thomas C. Fearneyhough, Russell L. Deter, Seung K. Park and Ivar K. Rossavle - Use of Femur Length, Abdominal Circumference Ratio in Detecting the Macrosomic Fetus. (**Journal of Radiology 1985:** 154:503-503).

27. Hadlock F.P., Harrist R.B., Carpenter R.J. et al. Sonographic estimation of fetal weight: The value of the femur length in addition to head and abdomen measurements. **Radiology 1984:** 535-540.

28. Abrams S.L., Filly R.S. Curvature of Fetal Femur a normal Sonographic finding. **Radiology 156:** 490:1985).

29. Dicke M. Jeffrey, Diana L. Gray, Giuliana S. Songster, James Crane - Fetal Biometry as a screening tool for the detection of chromosomally abnormal pregnancies (**Journal, Obstet. Gynecol.** 74:726, 1989).

30. Sarti D.A., Crandell B.F., Winter J. - Correlation of Biparietal and Fetal body measurements during 12-26 weeks gestation. **A.J.R.** 137:87, 1981.

31. Thomas and Campbell - Ultrasound measurement of the fetal head to abdominal circumference ratio in the assessment of growth retardation. **British Journal** of Obstetrics Gynecology. (1977:84;165-174).

32. Varma T.R. - Prediction of delivery date by ultrasound cephalometry. (**J. Obstet. Gynecology for Commonwealth** 80:316, 1973).

33. Yagel A. Adoni, S. Oman, Y. Wax and D. Hochner-*Celnikie* - *A* statistical examination of the accuracy of combining femoral length and biparietal diameter as an index of fetal gestational age. (**British Journal of Obstetrics and Gynecology,** February 1986, Vol.93, pp.109-115).

34. Ye Ming-Neng, Luis Bracero, Kevin B. Reilly, Loise Martha, Michael *Aboulafia, Bruce A. Barrow* - Ultrasonic Measurement of the Femur Length as an index of fetal Gestational Age. (**Am. J. Obstet. Gynecol.** 144:519, 1982).

Zador I.E., Hertz R.H., Sokol R.J. et al - Sources of error in the estimation of Fetal Gestational Age. (**Am. J. Obstetrics** *Gynaecology 138:344, 1980).*

Nimrod Tole - Physicist PH.D., Senior Lecturer, Department of Diagnostic Radiology **University of Nairobi** - Ultrasound principles and application. Personal communication.

Barry B. Goldberg, Alfred B. Kurtz - Atlas of Ultrasound measurements, Chapters 24, 25 & 26 pp. 264-419. **YEARBOOK MEDICAL PUBLISHERS**, Inc. 1st *Edition.*

38. Callen W. Peter - Textbook of Ultrasonography in Obstetrics and Gynaecology, 2nd Edition, Chapter 4, 1988, **W.B. Saunders, Harcourt Brace Jouanarich,** Inc.).

39. Fleischer C. Arthur, James Jr. & A. Everrette - Diagnostic Sonography - Principles and Clinical Applications, 1989. **W.B. Saunders Company.**

40. Grainger G.R. and Allison J.D. - Diagnostic Radiology Vol. 3 Chapter 80 from pp. 1563-91, **Churchill Livingstone, 1986.**

41. Sabbagha E. Rudy - Diagnostic Ultrasound applied to Obstetrics and Gynaecology, 1980. **By Harper and Row Publishers, Inc.**

42. Sander C. Roger, James Jr., Everette A. - The Principles and Practice of Ultrasonography in Obstetrics and Gynaecology, 2nd Edition, 1980. **(Appleton - Century crafts Publishing Division of Prentice Hall, Inc.).**

43. Suthon David - Textbook of Radiology and Imaging, 4th Edition, Volume two - Churchill Livingstone Publishers. Printed and bound in Great Britain by **William Clowers Limited, Beccles and London.**

44. Beazley J.M., Underhill R.A. - Fallacy of the fundal height. **British Medical Journal** 4:404, 1970.

45. Campbell S., Wilkin D. - Ultrasonic measurement of fetal abdomen circumference in the estimation of fetal weight (**British Journal of Obstetrics and** *Gynaecology Vol.82 No.9 September 1975*).