TITLE

"A CORRELATIVE STUDY OF THE VARIOUS GESTATIONAL AGE PARAMETERS OF OUR LOCAL POPULATION ON ULTRASOUND."

This dissertation is submitted in part fulfilment for the degree of Masters of Medicine in Diagnostic Radiology of the University of Nairobi.

November 1998
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DECLARATION

CANDIDATE

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

Signed ....

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This dissertation has been submitted for examination with my approval as University Supervisor.

Signed...................................

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DEDICATION

I wish to dedicate this thesis to *my parents*, without whose inspiration, support and prayers; I would not have reached this juncture.

ACKNOWLEDGEMENTS

I sincerely wish to express my profound word of thanks to Prof. J.M.K. Kitonyi, my supervisor, for his valuable constant guidance, advice and suggestions provided throughout the preparation of this dissertation.

I also wish to thank the rest of the academic staff of the Department of Diagnostic Radiology, University of Nairobi, for their contribution towards this dissertation.

I am indebted and thank Dr. Saleem Malik for permission to carry out the study at the Aga Khan Hospital, Nairobi.

I am grateful to Mr. Muniu of the Kenya Medical Research Institute for his expertise in the statistical analysis of the data.

I would like to express my appreciation to my wife, Anjum, for her constant encouragement throughout the preparation of this dissertation.

TABLE OF CONTENTS

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LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

SUMMARY

Obstetrical ultrasound, with time, has become an integral part of the management of ante-natal patients. The basis of this examination is the measurement of the gestational parameters.

Many studies have been carried out with the purpose of formulating gestational age tables; which are used to determine fetal age.

The purpose of this study was to determine differences, if any, which may exist between this research and those carried out previously on other ethnic groups.

This was a prospective study of 400 patients at Aga Khan Hospital, Nairobi, who had normal, uncomplicated pregnancies.

A total of 981 measurements were taken which consisted of the gestational sac (51), Crown-rump length (71), Abdominal Circumference (282), femur length (285) and Bi-parietal diameter (292).

Tables were formulated showing the number of observations, the mean and standard deviations of each measurement, at each week of gestation.

These tables were compared to other published data.

A significant result was found if the p value was more than 0.05.

Lower mean values were observed in this study when compared to those gestational age tables derived from research in other countries.

These differences could be attributed to environmental factors, genetics, socio-economic status and literacy levels.

Considering these differences, there appears to be a need for a comprehensive large scale study with an aim to formulate nomograms for our local population.

INTRODUCTION

The whole history of ultra-sound is quite short. The first practical application of ultrasound was the effort made by the French physicist, Paul Langerin, to detect submarines during the first world war. His work formed the basis of SONAR (sound navigation and ranging) detection, which was developed during the Second World War.

In the 1940s Karl Dussik in Austria, began to try to measure the transmission of ultrasound through the brain and produced images which he believed were the ventricles. In 1952, Tanaka and Wagai, from Japan, using an A-scan technique reported detection of intracerebral haematoma and brain tumours.

The real breakthrough of ultrasound in clinical practice came in gynaecology and obstetrics with the development of the first two-dimensional contact scanner in 1958 by the combined effort of Prof. Ian Donald and Physicist Tom Brown. Prof. Ian Donald used ultrasound to create the first ever human fetal images.

Since this pioneer work obstetrics ultrasound has advanced tremendously from A and B mode scanning to real -time imaging. Highly sophisticated computer assisted ultrasound imaging methods are now in operation to produce real time fetal images of remarkable clarity and detail.

Developments, however, continue and now three dimensional ultrasound fetal images are available. The basis of all these diagnostic ultrasound systems is the piezelectric crystals which are responsible for ultrasound images.

The fetus can be assessed in regard to viability, normal structure and growth. Growth begins at conception and continues to delivery. The rate is exponential from conception, progressively flattening out with advancing gestation.

At any given point in time, biological variation in the indices of fetal growth are inversely proportional to the rate of growth.

This relationship forms the basis of the rule namely the accuracy of ultrasound for estimating gestational age is inversely related to the duration of gestation.

The accuracy of the fetal age is of fundamental importance in obstetrics practice. To the mother the information regarding her expected date of delivery helps in planning for the arrival of her child; avoids unnecessary emotional problems caused by prolonged hospitalization and helps reduce costs.

To the obstetrician, the information is critical since recognition of disease and subsequent management are to a large extent dependent upon knowing the fetal age. It makes possible the reliable use of many biochemical tests, in which the levels are dependent on the weeks of pregnancy. The fetal measurements also form the basis for later clinical decisions such as the timing of delivery in risk pregnancies.

However, the patients inability to recall the starting date of the last menstrual period correctly, the use of oral contraceptives, subsequent pregnancy in the presence of lactational ammenorrhea, patient obesity, the presence of uterine leiomyoma and the subjective nature of maternal reporting of "quickening", all confuse the clinicians estimate of fetal age.

Among others, the various gestational age parameters used to assess fetal growth are the gestational sac measurement, crown-rump length, bi-parietal diameter, femoral length and abdominal circumference. All these parameters have now been firmly established as being reliable and accurate in assessing fetal age in utero at various stages of gestation.

These fetal measurements have been tabulated to form nomogram tables to estimate gestational age. These fetal age tables form the basis of obstetrical ultrasound.

LITERATURE REVIEW

Ultrasound has now become an integral part of the obstetrical management of patients. This is because of the non-invasive nature (1); its safety record but above all because of the accuracy of ultrasound in the detection of fetal age.

Gestational Sac

Hellman and co-workers were the first group to publish measurement data on the growth of the gestational sac in the first trimester of pregnancy(2). The gestational sac measurement was the mean of its anteroposterior, longitudinal and transverse diameters.

Joupilla, Koharn and Kaufman (3) in larger studies also derived their growth curves from means gestation sac diameters, although, in these series the mean were calculated from the greatest and smallest diameters of the sac as depicted on a longitudinal sac. Despite this difference their curves were very similar to those of Hellman et al.

Robinson(4) initially, demonstrated that the gestational sac volume measurements can also be used in fetal growth monitoring and are of considerable importance in the objective diagnosis of early blighted ova (anembryonic pregnancy) where the most striking abnormality is the absence of a formed fetus within the gestational sac.

Robinson (4), also determined that when a single internal diameter of the sac or an average of AP, transverse and lateral diameters are used to calculate the gestational age, the variation for 90% of cases is approximately $\pm$ one week. When the volume of the sac was calculated from the sum of cross-sectional areas of parallel scan the variation was reduced to $\pm$ 5 days. However, this measurement is not used routinely as special care is needed to see that sections are taken at precise intervals.

The size of the gestational sac increases rapidly from the fourth to tenth menstrual week enlarging from one to approximately six centimetres in gestational sac diameter (5).

Lack of growth or decrease in size of the gestational sac confirms non-viable pregnancy. If a question of viability arises, a repeat scan is recommended after seven to ten days. In a normal pregnancy the gestational sac should enlarge by approximately one centimetre in diameter (6).

The majority of gestational sacs are situated in the fundal or mid-uterine segments. A small percentage have a low implantation site (7).

Fetal Crown-rump length

In 1973, Robinson (8) introduced a new approach to the problem of assessing gestational age in the first trimester of pregnancy by devising a technique for the measurement of the fetal crown-rump length.

In this context, the term 'crown-rump length' is used rather loosely, as the parameter measured is really the longest, demonstrable length of the fetus excluding the limbs. This measurement is not necessarily identical to that of the embryological crown-rump length, since no account is made of the variations in the degree of flexion of the fetal body (9).

The accuracy of crown-rump length measurements as a means of predicting gestational age has been evaluated both clinically (8) and statistically (10). In the clinical study, it was found that the ultrasonic estimate of age in a series of 35 patients with "certain dates", was within three days of the menstrual age in all but one patient. The statistical study showed that a prediction could be made within $\pm$ 4.7 days in 95% of cases.

A study done by Drumm (11) also found crown-rump length to be an accurate predictor of gestational age.

Kurjak and co-workers (12) confirmed the accuracy of crown-rump length in determining fetal gestational age.

It is now a well documented fact beyond any reasonable doubt, that early crown-rump length measurements (between 6.5 and 10 weeks) is the single most accurate method of pregnancy dating (13).

However, towards the beginning of the second trimester the crown-rump length begins to show a substantial increase in biological variation.

Fetal Bi-parietal diameter

The crown-rump length is a technique that can be used with accuracy until approximately 12-13 weeks; when, it becomes difficult to get ideal maximal fetal length measurement. From this date on, the bi-parietal diameter is the preferred technique.

The bi-parietal diameter was the first fetal dimension to be measured by ultrasound.

A simple A-mode technique was used to demonstrate on an oscilloscope, reflections of the ultrasound beam by anterior and posterior walls of the skull and in the midline, by the falx cerebri (38).

With the evolution of the static B-scanner, the combined A and B mode technique was developed to give greater sophistication to measurement of the bi-parietal diameter (39).

The bi-parietal diameter is often measured as early as 11 weeks. By 13 weeks until approximately 30 weeks, the bi-parietal diameter represents a reasonably accurate method of detecting the fetal age (15,16).

Campbell (15) stated, that if bi-parietal diameter measurements were made between 20 to 30 weeks gestation, the accuracy of the period of gestation would be within ± 8.4 days in 95% of cases.

Beyond 30 weeks, in the last trimester, the accuracy in predicting fetal age using bi-parietal diameter is significantly decreased; there is a standard deviation of over two weeks because of the variability in head growth at this stage (14).

In separate studies, Shepard (17), Campbell (18) and Sabbagha (19) concluded that the inaccuracies of the measurement of the bi-parietal diameter were as much as ± 3.5-4 weeks at term.

At Kenyatta National Hospital, Rogo (20), made a total of 331 measurements of bi-parietal diameter in Kenyan women and created a nomogram. He found the values to be lower than those obtained from the Caucasian population.

In a study carried out in 1981, Rubowitz and Goldberg (21), found that bi-parietal diameter measurements tended to be larger in Negroid infants at 34 weeks gestation, even though at 20 weeks they were not large for dates.

It has been noted that proper measurement of bi-parietal diameter may be difficult in deeply engaged fetal head and breech presentation (22). Yeh et al also noted that in pre-rupture of membranes, the bi-parietal diameter measurement error by ultrasound can be very large. He also concluded, of course, that in a hydrocephalic fetus, the measurement of bi-parietal diameter as a predictor of gestational age to be useless.

However, bi-parietal diameter can be used in the third trimester as a means of following IUGR and as an indication of the appropriate time for an amniocentesis to determine fetal maturity (23).

Fetal femur measurement

Fetal femur measurement is a relatively new method of fetal age determination; first described by O'Brien and Queenan (24) and subsequently investigated in detail by Hadlock et al (25).

In the study of O'Brien and Queenan, the measurements correlated well with the gestational age during the period of 14-22 weeks with an estimate to within 6.7 days at the 95% confidence level.

In the study of Hadlock et al, (25) the error of estimate varied with gestational age, ranging from an average estimate error of one week before 20 weeks to an error of two weeks after 34 weeks gestation.

Seeds et al (20) found the femur length to be significantly accurate only upto 24 weeks, but Yeh et al (22) found it an accurate index of gestational age beyond this period.

Measurements of the fetal femur may be useful in situations other than to ascertain gestational age. There is a constant linear relationship between the growth of the fetal bi-parietal diameter and the growth of the femur length between 23-40 weeks (27).

This relationship can be used to assess symmetrical and asymmetrical intra-uterine growth retardation (28), fetal Macrosomia (29), osteogenesis imperfecta (25) and the evaluation of vitamin D status of the mother and their effect on fetal growth.

Fetal abdominal circumference

The fetal abdominal circumference was first investigated as a method of estimating fetal age by Hadlock and Deter (30) in 1982.

In contemporary obstetrics the measurement is not frequently used for fetal age determination but is of critical importance in estimating fetal weight and weight gain. This is because the use of abdominal circumference measurements have not been shown to enhance predictive accuracy of gestational age; but is considered to introduce measurement error.

Hadlock et al (30) found the abdominal circumference measurement to be a worse predictor of gestational age than the bi-parietal diameter, except after 36 weeks.

Nevertheless, abdominal circumference measurement may be helpful in cases in which the bi-parietal diameter measurement is technically impossible or in cases in which moulding of fetal head may affect the accuracy of the bi-parietal diameter measurement (31).

It has been proposed that the abdominal circumference is the most accurate determination of asymmetrical fetal growth retardation (32).

It is a standard practice now to combine two or more parameters where possible.

Studies have shown that prior to 32 weeks the optimum combination of parameters include bi-parietal diameter, abdominal circumference and femur length measurements. However, after 30 weeks the bi-parietal diameter measurement becomes less reliable (25, 33).

AIM

The overall aim of the study is to correlate the various gestational age parameters of our local population on ultrasound.

SPECIFIC OBJECTIVES

1) To obtain the following measurements:-

   a) Gestational sac

   b) Crown-rump length

   c) Bi-parietal diameter

   d) Femur length

   e) Abdominal circumference

2) Using the above data, to create a nomogram for the above parameters.

3) To compare the nomograms from this study with those obtained from Caucasian population.

STUDY DESIGN

This was a prospective study involving 400 patients.

JUSTIFICATION

Many investigations have been carried out to establish the relationship between gestational parameters and fetal age; but mainly in the Caucasian population.

However, genetic influences on growth rate, socio-economic status of the parents and altitude are all known to effect growth rate. These variables no doubt influence the growth rate of the ultrasound indices used to measure fetal age.

The mean birth weight in African population tends to be lower compared to that within Caucasians. A study in Nigeria confirmed this and reported bi-parietal diameter values to be generally lower.

To date, two studies on bi-parietal diameter measurements have been undertaken at Kenyatta National Hospital (Rogo and Dhadialla) which found lower bi-parietal diameter values as compared to other studies.

The parameters used in our country are those obtained from other ethnic race groups.

A study of all the parameters is needed to firmly establish whether there is a need of nomograms tailored to our local population.

ETHICAL CONSIDERATIONS

1. The confidentiality of the patients were maintained. No names (only number of patients). were recorded on the data collection forms.

2. Safety of ultrasound

This diagnostic method has been used in obstetrics for almost 40 years. In all this time there has not been a single reproducible deleterious fetal effect reported as a consequence of this energy exposure.

At the University of Manitoba, U.S.A., more than 10,000 children exposed to ultrasound in utero have been followed without recognition of any adverse effects.

Starch and associates (34) found no short or long term effects of ultrasound. They examined 425 children exposed to intra-uterine ultrasound at birth and at 7-12 years of age.

At birth, they measured the Apgar score, birth weight and looked for congenital abnormalities and neonatal infections.

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At 7-12 years, nerve and conduction deafness measurements were taken and complete neurological examination was conducted. No biologically significant difference between exposed and unexposed children was observed.

Furthermore, data of second generation effects of ultrasound exposure are now becoming available, again, showing no recognisable adverse effect of ultrasound on exposed individual progeny.

Thus, although by definition, the definitive answer concerning the safety of ultrasound may never be reached; the results to date imply remarkable safety.

LIMITATIONS

1) The study comprised of 400 patients.

2) Equal representation of all the gestational parameters in this study was not possible as patients usually begin ante-natal care rather late in their pregnancies.

3) Inter-observer error has a negligible but definite contribution to gestational age parameters. It has been estimated that even the most experienced observer has a measurement error of at least 1 mm and perhaps as high as 2 mm when measuring bi-parietal diameter (35)

4) Mild bowing of the femur is observed from 18 weeks gestation. This was described by Queenan (36) and Warda (37). However, they concluded that a straight line measurement is appropriate in contrast to measuring it along the curvature of the bone.

SUBJECTS, MATERIALS AND METHODS

Subjects

All the patients recruited in this study were those who presented for obstetrical ultrasound at the Department of Radiology, Aga Khan Hospital, Nairobi.

The history, age, race, parity and last menstrual period were noted and the following exclusion criteria was observed.

1. Uncertain date of last menstrual period.
2. Maternal disease or medication which could effect the growth of the fetus such as:-
   a) Diabetes Mellitus
   b) Renal Disease
   c) Anemia
   d) Hypertension
   e) Chronic infections
   f) Pre-eclampsia
3. History of complications during pregnancy such as bleeding per vaginum and severe hypermesis gravidarum.
4. Multiple pregnancies.
5. Fetal malformation.
6. Smoking

Hospital

The study was carried out at the Department of Radiology, Aga Khan Hospital, Nairobi.

This Department is chaired by a Consultant Radiologist and comprises of a state of the art, high resolution ultra-sound machine.

The hospital runs a full staffed Department of Obstetrics and Gynaecology with four ante-natal clinics weekly.

Equipment

The ultrasound machine used was a 'HDI 300' model manufactured by an American firm ATL (Advanced Technology Laboratories).

The machine is capable of real-time two dimensional (2D) imaging, Power (high definition zoom), colour and Dopplers Imaging. It comprises of a variety of scan heads like linear, curved, static and intracavity.

The obstetrical imaging was carried out by using a 3-5 MHZ transducer.

Physics of sound wave propagation

The principle of sound wave propagation in this machine is as in all ultrasound machines.

With diagnostic ultrasound (above 20,000 cycles per second), pulses of electric energy strike a piezoelectric crystal within the transducer. This causes the crystal to expand and contract, thereby using mechanical pressure waves into the tissues. As the sound waves propagate within the tissues (1540 m/sec), they encounter interfaces of different acoustic impedence (product of density and velocity of sound) and are reflected back to the transducer.

These reflected waves are converted into electronic signals that are processed and displayed on an oscilloscope screen.

Methodology

Patient preparation

No patient preparation was requested for except those who were in their early first trimester of pregnancy. These group of mothers were asked to have four to five glasses of water about two hours prior to the examination so as to obtain a full bladder.

A fully distended bladder accomplishes two goals:-

1. It displaces the echo-scattering bowel out of the pelvis thus providing an ultrasonic window into the pelvis.

2. Urine filled bladder serves as a reference of sonolucency for comparison of the echogenic properties of different structures.

Examination with a full bladder is not needed in the second trimester at which stage the gravid uterus displaces the bowel out of the pelvis.

With the patient lying supine and having applied coupling gel the following gestational parameters were recorded as described.

Gestational sac

After visualising the gestational sac; the measurements were taken inside the hyperechoic rim, including only the anechoic space, referred to as "inner to inner sac measurement".

If the sac was round only one dimension was taken, if it was ovoid, three measurements were taken and an average diameter was calculated.

The long axis and A.P. measurements were obtained from the sagittal image, the longitudinal axis measurement was first taken and the A.P. dimension measured perpendicular to it. The width measurement was taken from a transverse image.

Ultrasound scan 1: Measurement of the gestational sac.

Crown-rump length

Crown-rump length was obtained from an image of the embryo in its maximum longitudinal plane, by recording the distance between the crown of the head and the buttock.

Ultrasound scan 2: Measurements of the crown-rump length

Bi-parietal diameter

After locating the fetal head the oval longitudinal axis was defined by locating the mid-line echo from the falx cerebri and the rectangular cavum septum pellucidum.

The bi-parietal diameter was measured from the outer calvarium to the far wall inner calvarium referred to as "leading edge to leading edge" technique; this dimension being the widest distance perpendicular to the midline echo.

Ultrasound scan 3: Measurement of the fetal bi-parietal diameter.

Femur length

The femur length was obtained after obtaining the fetal thigh in the longitudinal axis. The femur was measured along the long axis of the diaphysis; the osseous portion of the shaft.

The normal diaphysis has a straight lateral and curved medial border. A straight measurement was taken from one end to the other disregarding the curvature. The proximal and distal epiphyseal cartilages are not ossified and were excluded from the measurement.

Ultrasound scan 4: Measurement of the femur length.

Abdominal circumference

The standard plane for measurement is at the level of the intrahepatic part of the umbilical vein. This was identified by locating the long axis of the fetal aorta. The transducer was then rotated through 90° to obtain a cross-sectional view which was as circular as possible. By moving the transducer in the long axis of the fetus the umbilical vein was identified and followed to its intrahepatic level.

With this correct plane the abdominal circumference was measured by using a map reader to trace the outer limits of the abdomen.

Ultrasound scan 5: Measurement of the fetal abdominal circumference.

DATA MANAGEMENT AND ANALYSIS

Data was entered into a microcomputer. Data cleaning and validation was done before analysis.

Analysis involved descriptive statistics like frequencies, means and standard deviations. For comparison of the results of this study with other published data, the students 't' test was applied using the means and standard deviations or standard errors.

Computation of student 't' statistics was done and evaluation of the significance level (p - value) of the 't' value was done.

A significant result was found if $p < 0.05$ (two tailed test).

RESULTS

A total of 400 patients seen at Aga Khan Hospital had recordings of gestational sac, crown-rump length, biparietal diameter, femur length and abdominal circumference.

The distribution of patients by origin was 132 (33%) Asians, 248 (62%) Africans and 20 (5%) European. The mean age of study patients was 27.52 years with a standard deviation of 4.81 years and the age ranged from 18 to 44 years. The age of 3 patients was not recorded. The age distribution by origin is shown in Table 1 and Figure 1.

Parity ranged from 0 to 7 with a mean of 1-13 and a standard deviation of 1.03 children and the distribution of parity by origin is shown in Table 2 and Figure 2.

Table 3 and Figure 3 shows the number for each type of measurement that were recorded. Biparietal diameter had the highest (73%) and gestational sac had the lowest (12.75%) recording.

ABLE 1: DISTRIBUTION OF AGE BY ORIGIN

Age group in years	Asian Number	%	African Number	%	European Number	%	Total Number	%
15 - 19	5	62.5	3	37.5	0	0	8	2.0
20 - 24	44	42.3	57	54.8	3	2.9	104	26.2
25 - 29	53	36.6	89	61.4	3	2.1	145	36.5
30 - 34	24	22.0	73	67.0	12	11.0	109	27.5
35 - 39	4	18.2	17	77.3	1	4.5	22	5.5
40 - 44	1	11.1	7	77.8	1	11.1	9	2.3
Total	131	33.0	246	62.0	20	5.0	397	100

Three patients did not have their age recorded.

TABLE 2: DISTRIBUTION OF PARITY BY ORIGIN

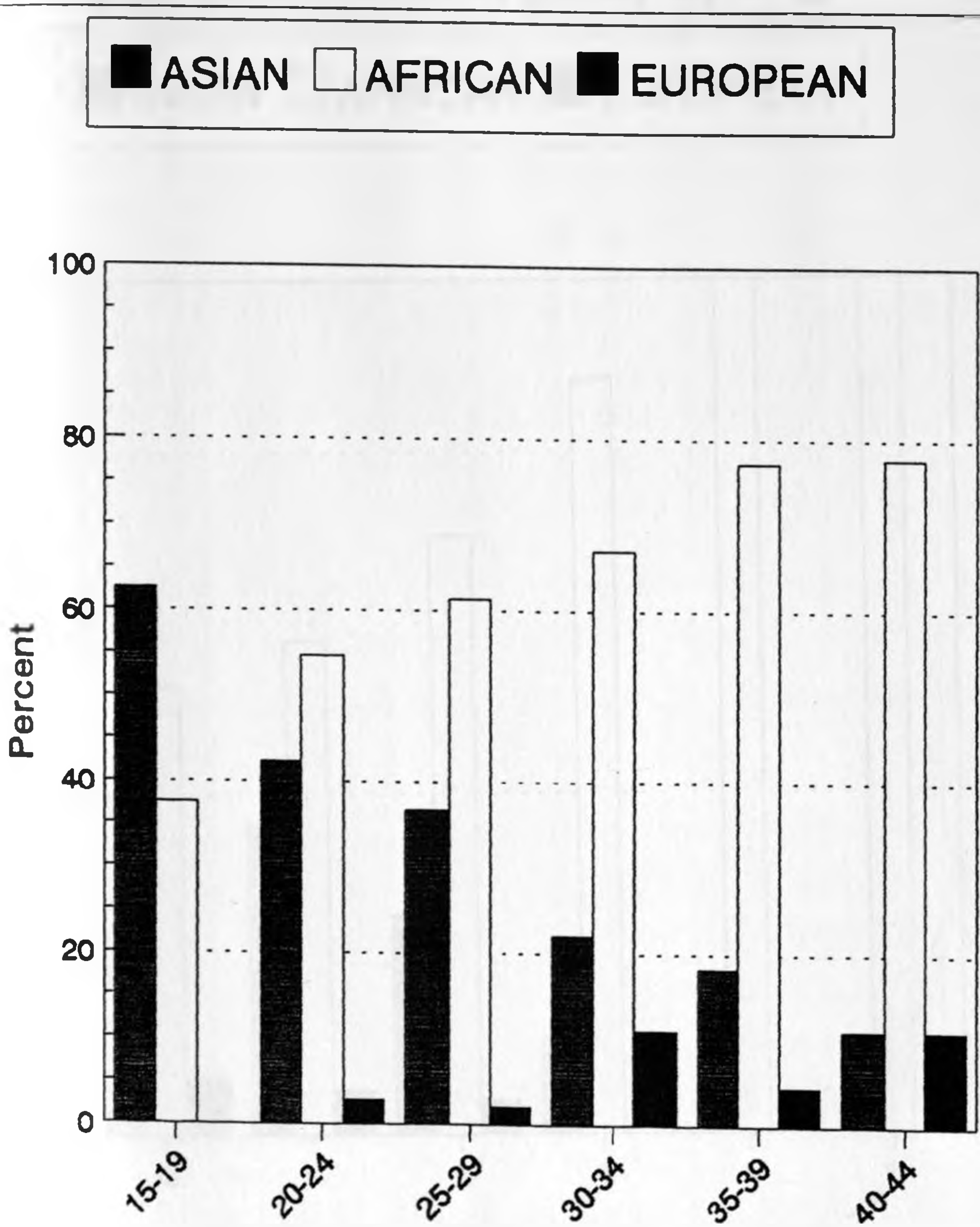
Parity	Asian Number	%	African Number	%	European Number	%	Total Number	%
0	48	40.3	63	52.9	8	6.7	119	29.9
1	56	36.8	88	57.9	8	5.3	152	38.2
2	25	25.8	68	70.1	4	4.1	97	24.4
3	3	11.5	23	88.5	0	0	26	6.5
4	0	0	1	100	0	0	1	0.3
≥ 5	0	0	3	100	0	0	3	0.8
Total	132	33.2	246	61.8	20	5.0	398	100

Two patients did not have their parity recorded.

TABLE 3: DISTRIBUTION OF TYPE OF MEASUREMENT OBTAINED FROM 400 PATIENTS

Type of measurement	Number of measurements	Percent (n=400)
Biparietal diameter	292	73.0
Femur length	285	71.25
Abdominal circumference	282	70.5
Gestational sac	51	12.75
Crown-rump length	71	17.75
Total	981	

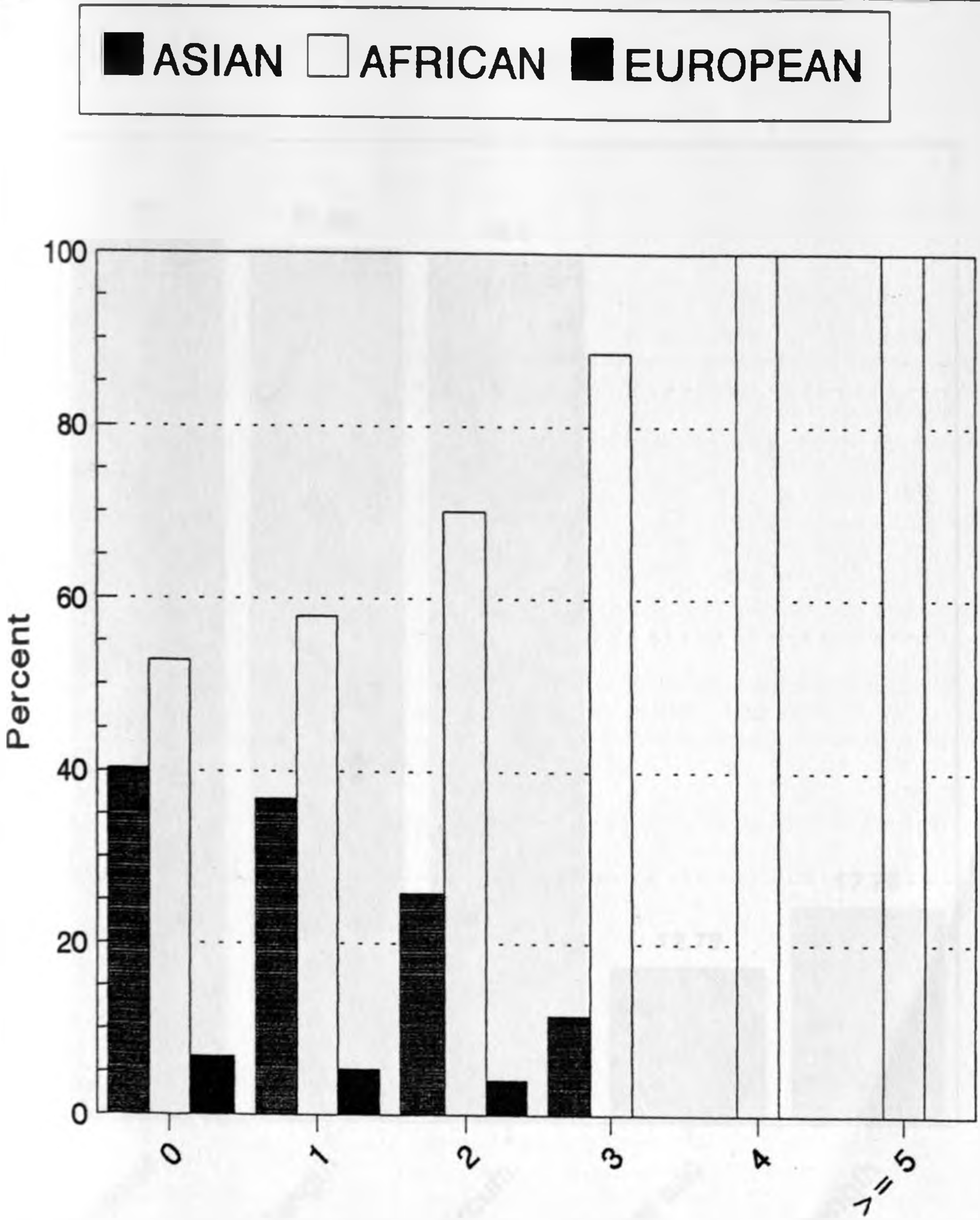
Fig 1: Distribution of age by origin



	15-19	20-24	25-29	30-34	35-39	40-44
SIAN	62.5	42.3	36.6	22	18.2	11.1
FRICAN	37.5	54.8	61.4	67	77.3	77.8
UROPEAN		2.9	2.1	11	4.5	11.1

Age group in years

Fig 2: Distribution of parity by origin



SIAN	40.3	36.8	25.8	11.5		
FRICAN	52.9	57.9	70.1	88.5	100	100
UROPEAN	6.7	5.3	4.1			

Parity

Fig 3: Distribution of type of measurement

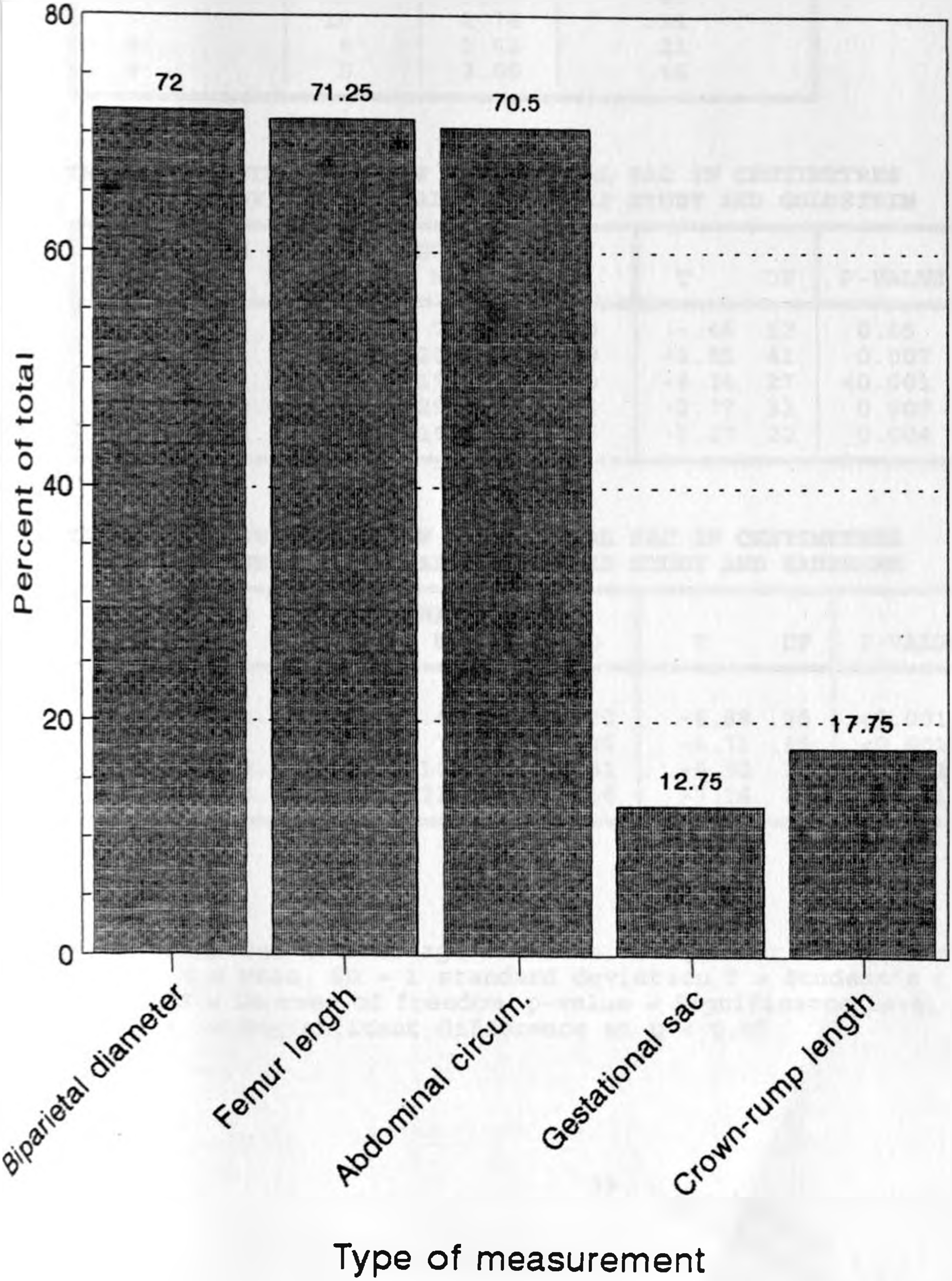


TABLE 4: DISTRIBUTION OF GESTATIONAL SAC (IN CENTIMETRES) BY GESTATIONAL AGE

Gestational age in weeks	Number	Mean	1 Standard deviation (SD)
5	7	.76	.11
6	23	1.12	.42
7	10	1.76	.31
8	6	2.63	.21
9	5	3.00	.16

TABLE 5: DISTRIBUTION OF GESTATIONAL SAC IN CENTIMETRES BY GESTATIONAL AGE : THIS STUDY AND GOLDSTEIN

	THIS STUDY			GOLDSTEIN					
GESTW	N	M	SD	N	M	SD	T	DF	P-VALUE
5	7	.76	.11	7	.80	.20	-.46	12	0.65
6	23	1.12	.42	20	1.40	.20	-2.85	41	0.007 *
7	10	1.76	.31	19	2.60	.10	-8.34	27	<0.001 *
8	6	2.63	.21	29	2.90	.25	-2.77	33	0.009 *
9	5	3.00	.16	19	3.30	.25	-3.27	22	0.004 *

TABLE 6: DISTRIBUTION OF GESTATIONAL SAC IN CENTIMETRES BY GESTATIONAL AGE : THIS STUDY AND HANSMANN

	THIS STUDY			HANSMANN					
GESTW	N	M	SD	N	M	SD	T	DF	P-VALUE
5	7	.76	.11	.	.	.	.	.	
6	23	1.12	.42	4	2.30	.20	-8.88	25	<0.001 *
7	10	1.76	.31	7	2.70	.26	-6.71	15	<0.001 *
8	6	2.63	.21	18	3.50	.51	-5.90	22	<0.001 *
9	5	3.00	.16	22	4.00	.56	-7.16	25	<0.001 *

**

** GESTW = Gestational age in weeks; N = Number of observations
M = Mean; SD = 1 standard deviation T = Student's t statistic;
DF = Degrees of freedom p-value = Significance level (two tailed
* = Siginificant difference at $p < 0.05$

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Fig 4: Distribution of gestational sac by gestational age

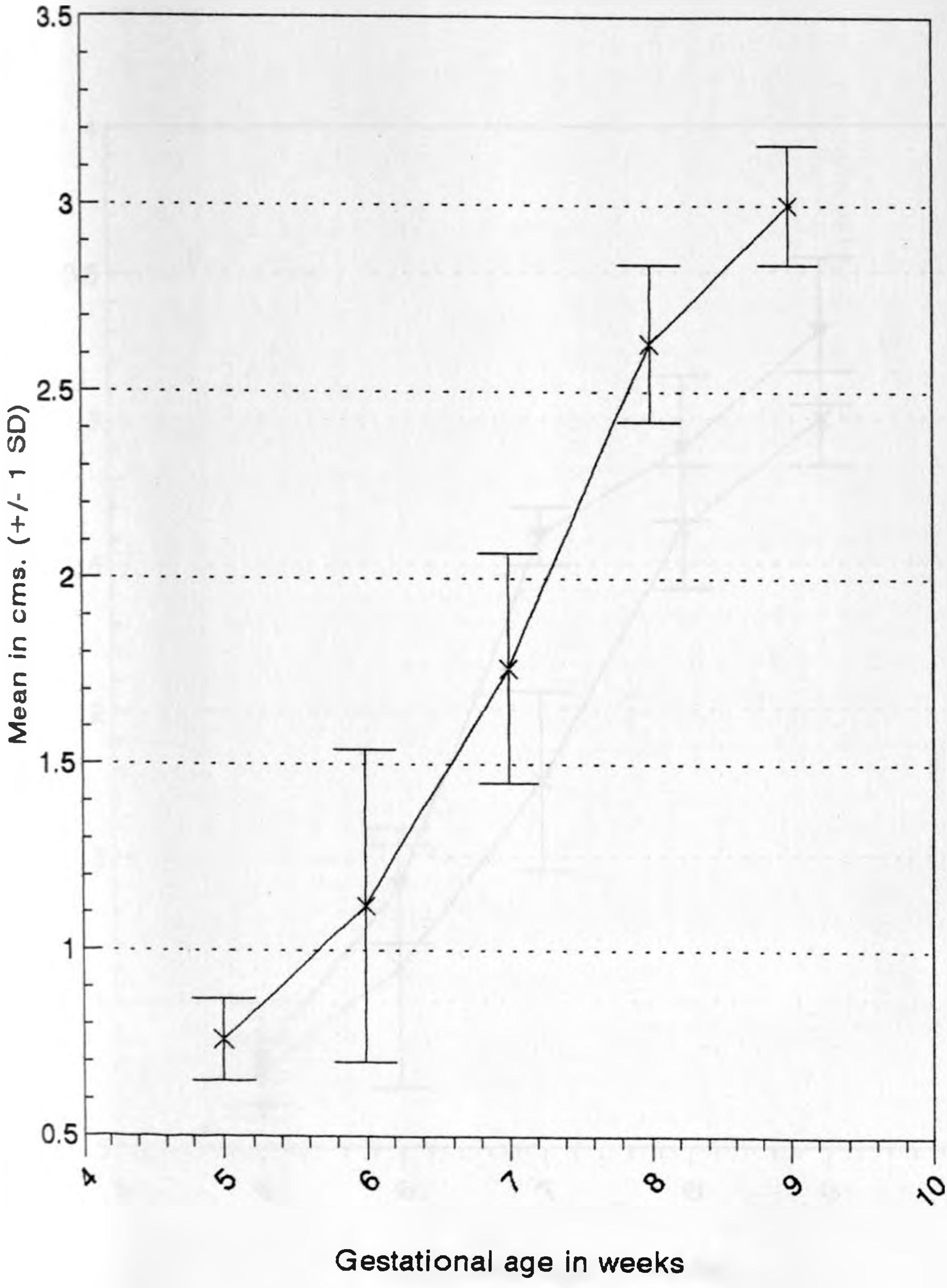


Fig 5: Distribution of gestational sac by gestational age

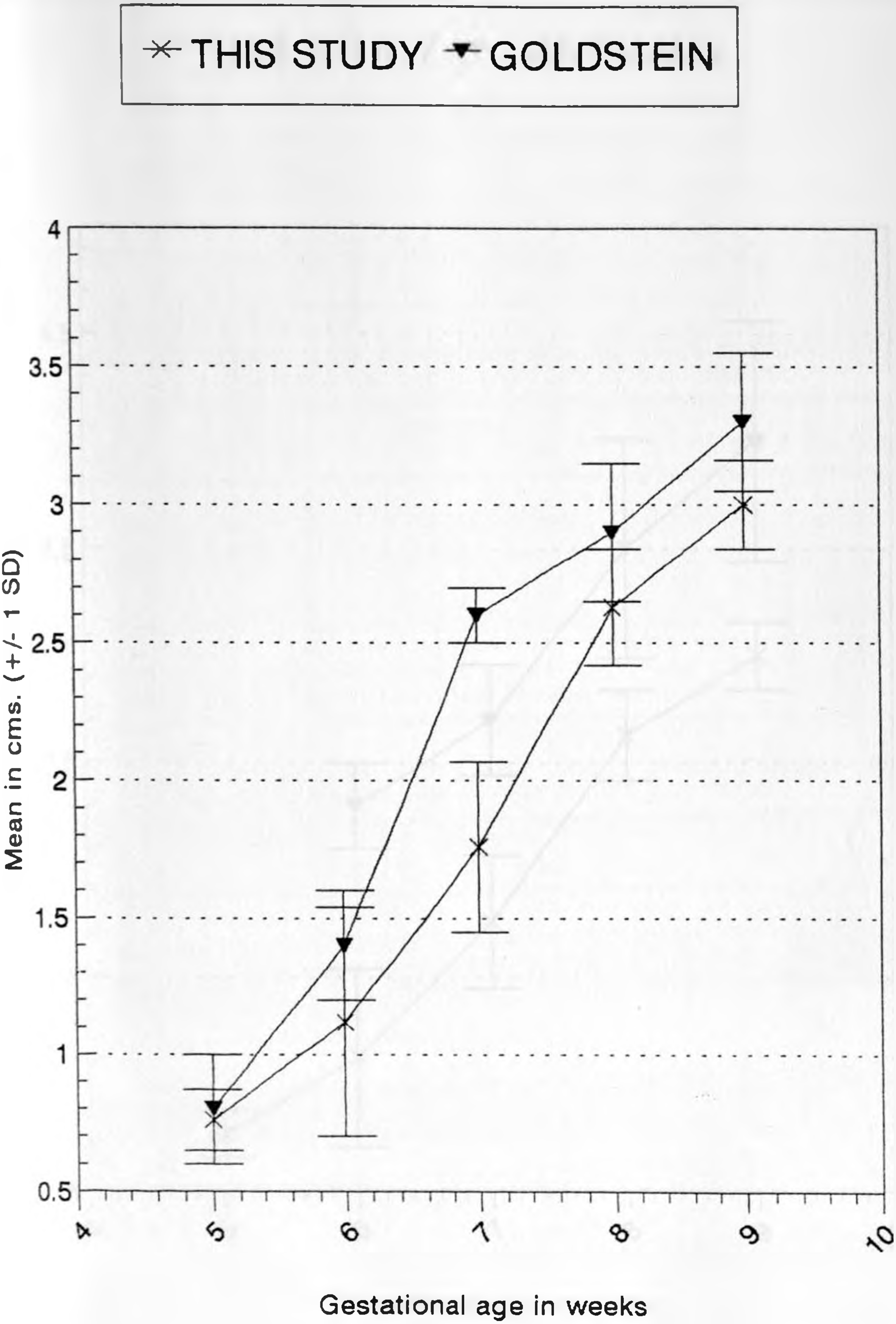


Fig 6: Distribution of gestational sac by gestational age

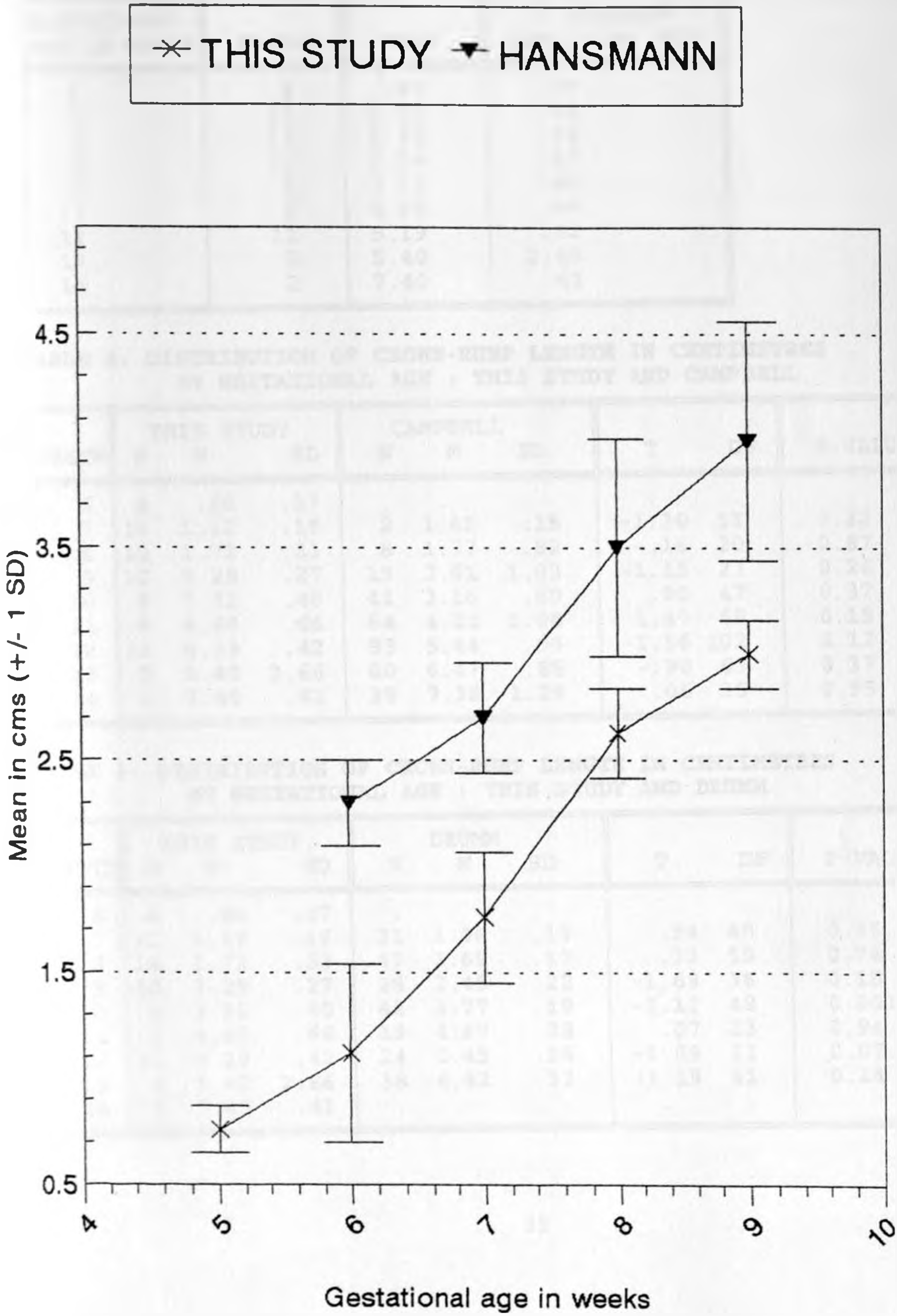


TABLE 7: DISTRIBUTION OF CROWN-RUMP LENGTH (IN CENTIMETRES) BY GESTATIONAL AGE

Gestational age in weeks	Number	Mean	1 Standard deviation (SD)
6	4	.60	.17
7	11	1.12	.18
8	14	1.72	.33
9	10	2.29	.27
10	8	3.32	.40
11	6	4.65	.66
12	11	5.19	.42
13	5	5.40	2.66
14	2	7.40	.41

TABLE 8: DISTRIBUTION OF CROWN-RUMP LENGTH IN CENTIMETRES BY GESTATIONAL AGE : THIS STUDY AND CAMPBELL

	THIS STUDY			CAMPBELL					
GESTW	N	M	SD	N	M	SD	T	DF	P-VALUE
6	4	.60	.17	.	.	.	.	.	
7	11	1.12	.18	2	1.45	.35	-1.30	11	0.22
8	14	1.72	.33	8	1.77	.82	-.16	20	0.87
9	10	2.29	.27	15	2.61	1.03	-1.15	23	0.26
10	8	3.32	.40	41	3.16	.69	.90	47	0.37
11	6	4.65	.66	64	4.21	1.04	1.47	68	0.15
12	11	5.19	.42	93	5.44	.94	-1.56	102	0.12
13	5	5.40	2.66	60	6.47	.85	-.90	63	0.37
14	2	7.40	.41	35	7.38	1.29	.06	35	0.95

TABLE 9: DISTRIBUTION OF CROWN-RUMP LENGTH IN CENTIMETRES BY GESTATIONAL AGE : THIS STUDY AND DRUMM

	THIS STUDY			DRUMM					
GESTD	N	M	SD	N	M	SD	T	DF	P-VALUE
6	4	.60	.17	.	.	.	.	.	
7	11	1.12	.18	31	1.06	.19	.94	40	0.35
8	14	1.72	.33	47	1.69	.17	.33	59	0.74
9	10	2.29	.27	28	2.45	.22	-1.68	36	0.10
10	8	3.32	.40	42	3.77	.19	-3.12	48	0.003 *
11	6	4.65	.66	19	4.67	.28	.07	23	0.94
12	11	5.19	.42	24	5.45	.26	-1.89	33	0.07
13	5	5.40	2.66	38	6.82	.33	-1.19	41	0.24
14	2	7.40	.41	.	.	.	.	.	

Fig 7: Distribution of crown-rump length by gestational age

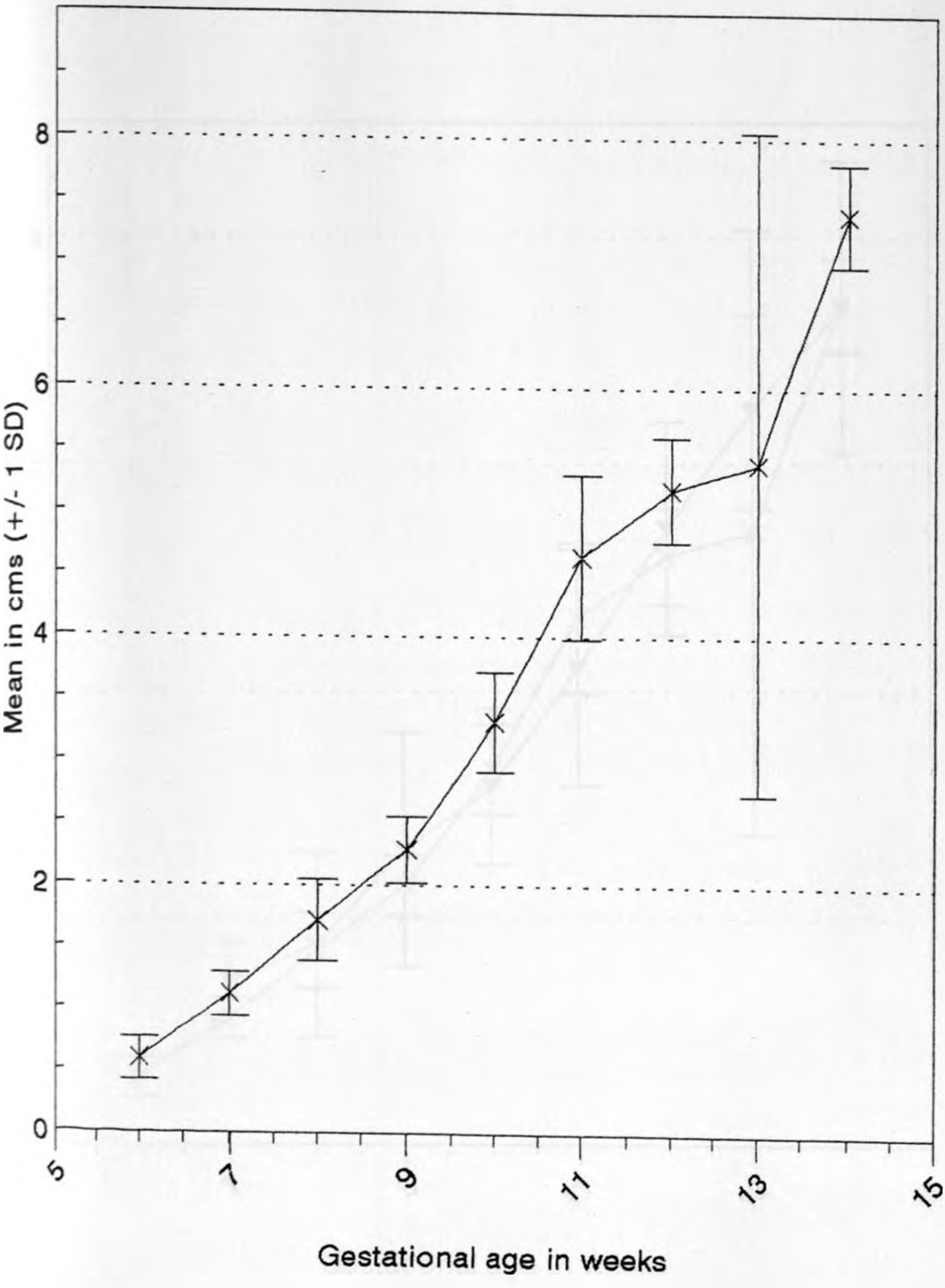


Fig 8: Distribution of crown-rump length by gestational age

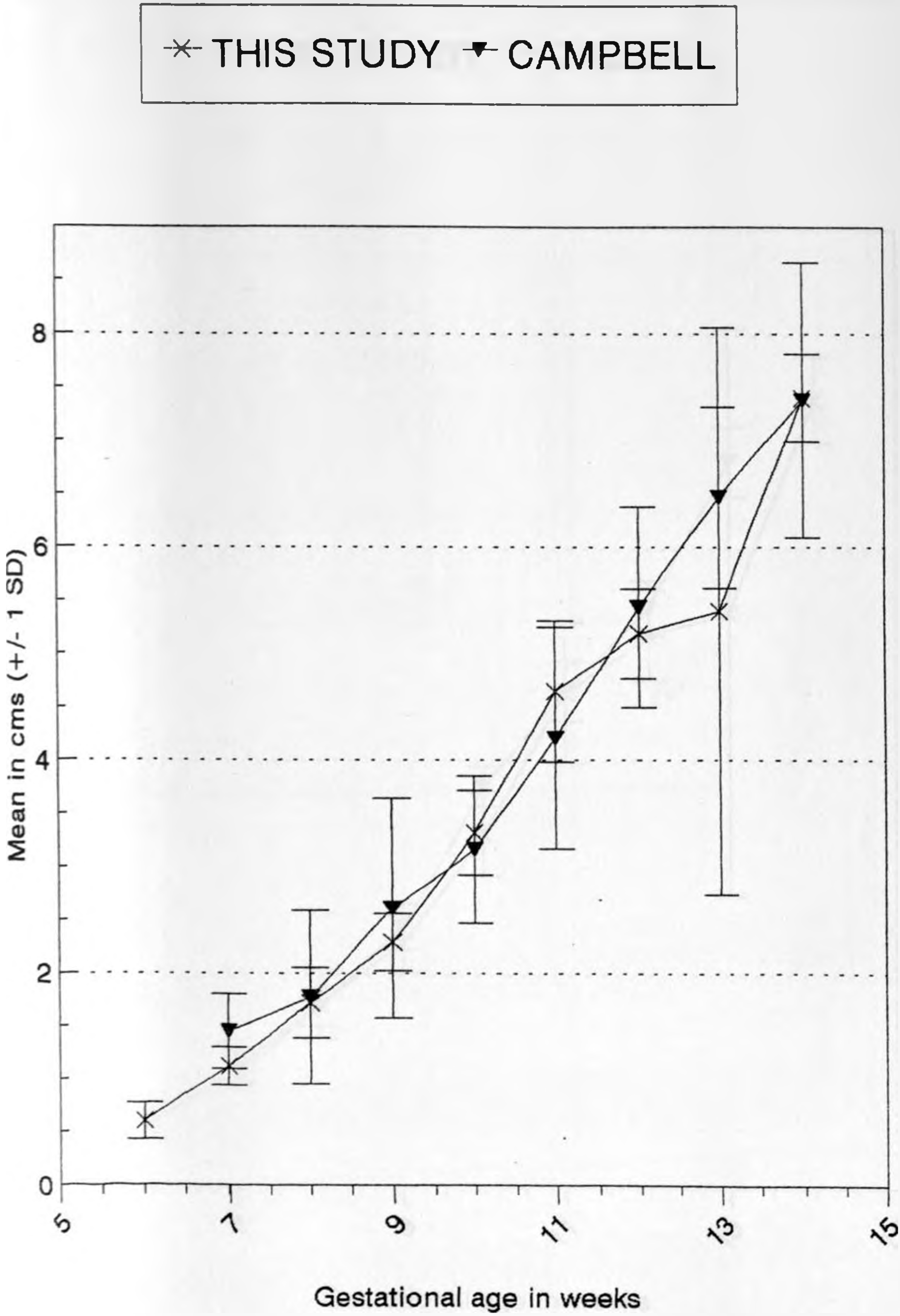


Fig 9: Distribution of crown-rump length by gestational age

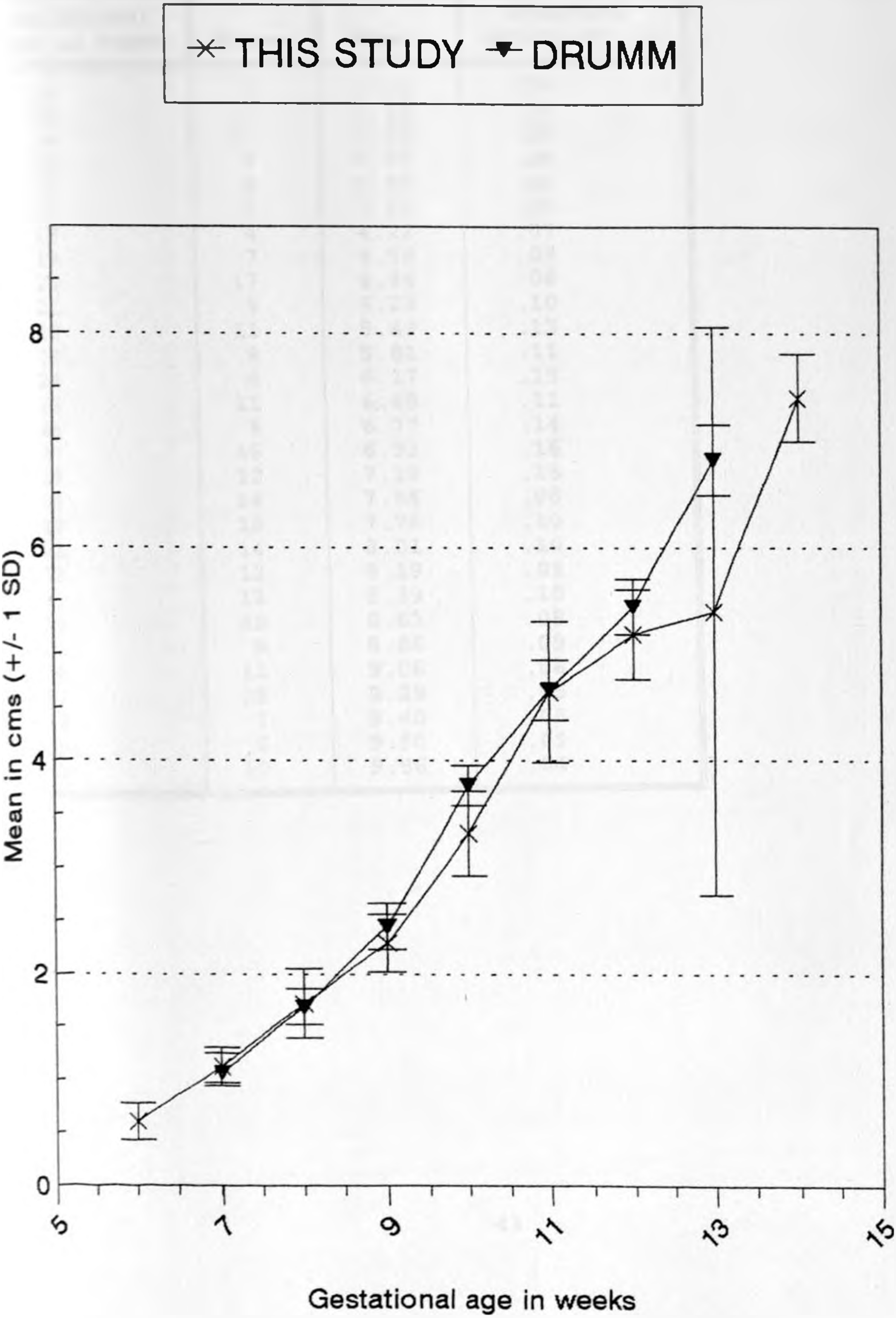


TABLE 10: DISTRIBUTION OF BIPARIETAL DIAMETER (IN CENTIMETRES) BY GESTATIONAL AGE

Gestational age in weeks	Number	Mean	1 Standard deviation (SD)
12	3	2.46	.09
13	1	2.45	.00
14	12	2.91	.23
15	5	3.27	.14
16	8	3.52	.12
17	8	3.92	.15
18	4	4.22	.07
19	7	4.56	.09
20	17	4.94	.08
21	9	5.23	.10
22	11	5.49	.13
23	8	5.81	.11
24	6	6.17	.15
25	11	6.48	.11
26	8	6.77	.14
27	16	6.93	.16
28	12	7.18	.15
29	14	7.55	.08
30	15	7.76	.10
31	14	8.01	.10
32	12	8.19	.09
33	12	8.39	.10
34	20	8.63	.08
35	9	8.86	.09
36	12	9.06	.06
37	15	9.29	.05
38	7	9.40	.05
39	6	9.50	.09
40	10	9.56	.04

g 10: Distribution of biparietal diameter by gestational age

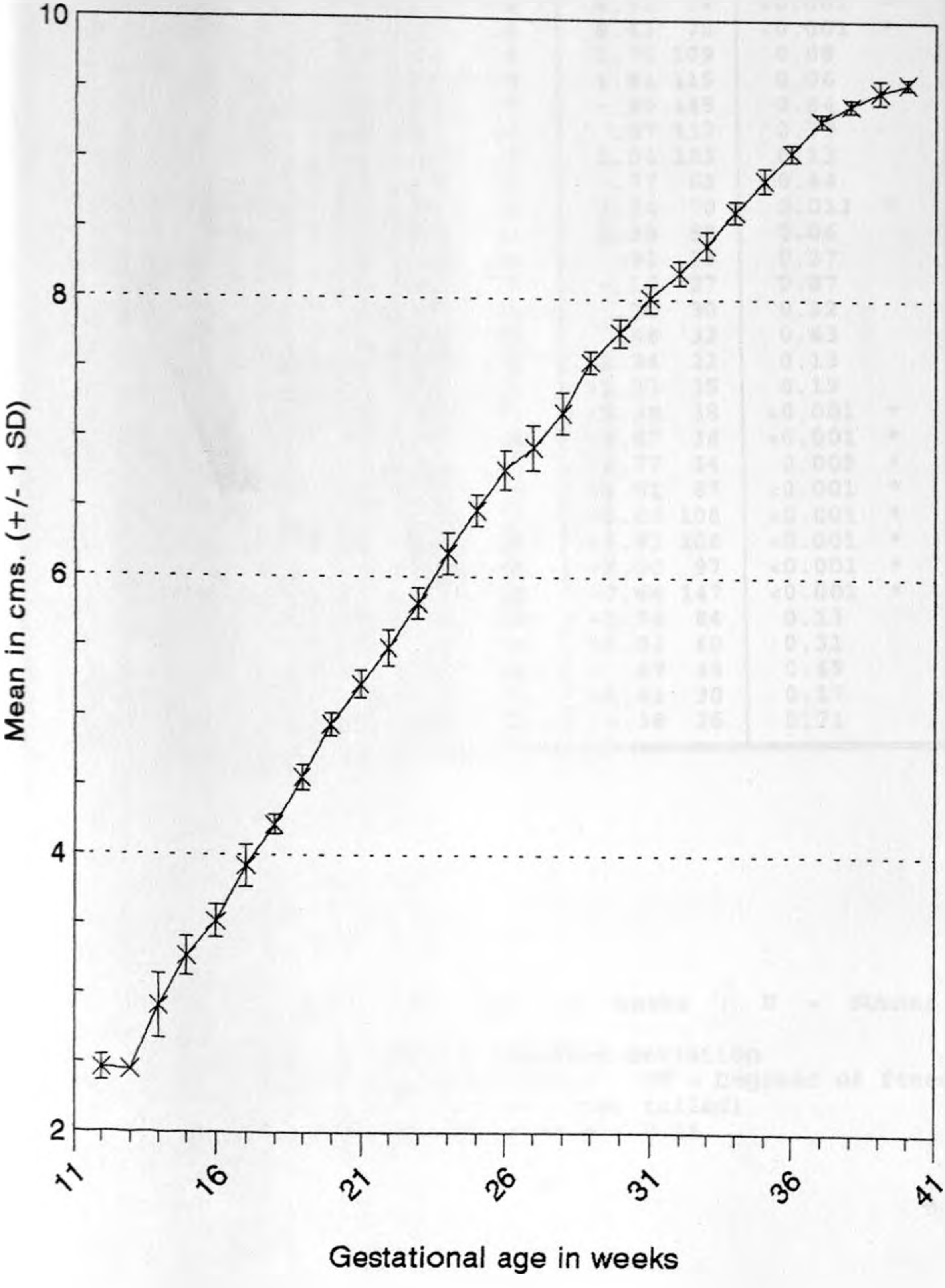


TABLE 11: DISTRIBUTION OF BIPARIETAL DIAMETER (IN CENTIMETRES) BY GESTATIONAL AGE : THIS STUDY AND CAMPBELL

GESTW	THIS STUDY N	M	SD	CAMPBELL N	M	SD	T	DF	P-VALUE	
12	3	2.46	.09	33	2.12	.30	4.62	34	<0.001	*
13	1	2.45	.00	71	2.17	.28	8.43	70	<0.001	*
14	12	2.91	.23	99	2.78	.32	1.76	109	0.08	
15	5	3.27	.14	112	3.14	.28	1.91	115	0.06	
16	8	3.52	.12	139	3.53	.29	-.20	145	0.84	
17	8	3.92	.15	126	3.87	.24	.87	132	0.39	
18	4	4.22	.07	101	4.15	.29	1.54	103	0.13	
19	7	4.56	.09	63	4.60	.31	-.77	68	0.44	
20	17	4.94	.08	55	4.82	.32	2.54	70	0.013	*
21	9	5.23	.10	45	5.12	.31	1.93	52	0.06	
22	11	5.49	.13	26	5.42	.34	.91	35	0.37	
23	8	5.81	.11	21	5.82	.23	-.16	27	0.87	
24	6	6.17	.15	26	6.16	.39	.10	30	0.92	
25	11	6.48	.11	23	6.42	.58	.48	32	0.63	
26	8	6.77	.14	16	6.59	.50	1.34	22	0.19	
27	16	6.93	.16	21	7.09	.52	-1.33	35	0.19	
28	12	7.18	.15	28	7.58	.32	-5.38	38	<0.001	*
29	14	7.55	.08	26	7.87	.34	-4.57	38	<0.001	*
30	15	7.76	.10	21	8.03	.43	-2.77	34	0.009	*
31	14	8.01	.10	75	8.22	.39	-4.01	87	<0.001	*
32	12	8.19	.09	98	8.57	.35	-8.66	108	<0.001	*
33	12	8.39	.10	98	8.67	.28	-6.93	108	<0.001	*
34	20	8.63	.08	79	8.94	.36	-7.00	97	<0.001	*
35	9	8.86	.09	140	9.16	.30	-7.64	147	<0.001	*
36	12	9.06	.06	74	9.14	.42	-1.54	84	0.13	
37	15	9.29	.05	47	9.35	.39	-1.03	60	0.31	
38	7	9.40	.05	40	9.35	.44	.69	45	0.49	
39	6	9.50	.09	26	9.62	.39	-1.41	30	0.17	
40	10	9.56	.04	18	9.59	.33	-.38	26	0.71	

[1]

[1] GESTW = Gestational age in weeks ; N = Number of observations
M = Mean ; SD = 1 standard deviation
T = Student's t statistic ; DF = Degrees of freedom
P-value = Significance level (two tailed)
* = Significant difference at $p < 0.05$

Fig 11: Distribution of biparietal diameter by gestational age

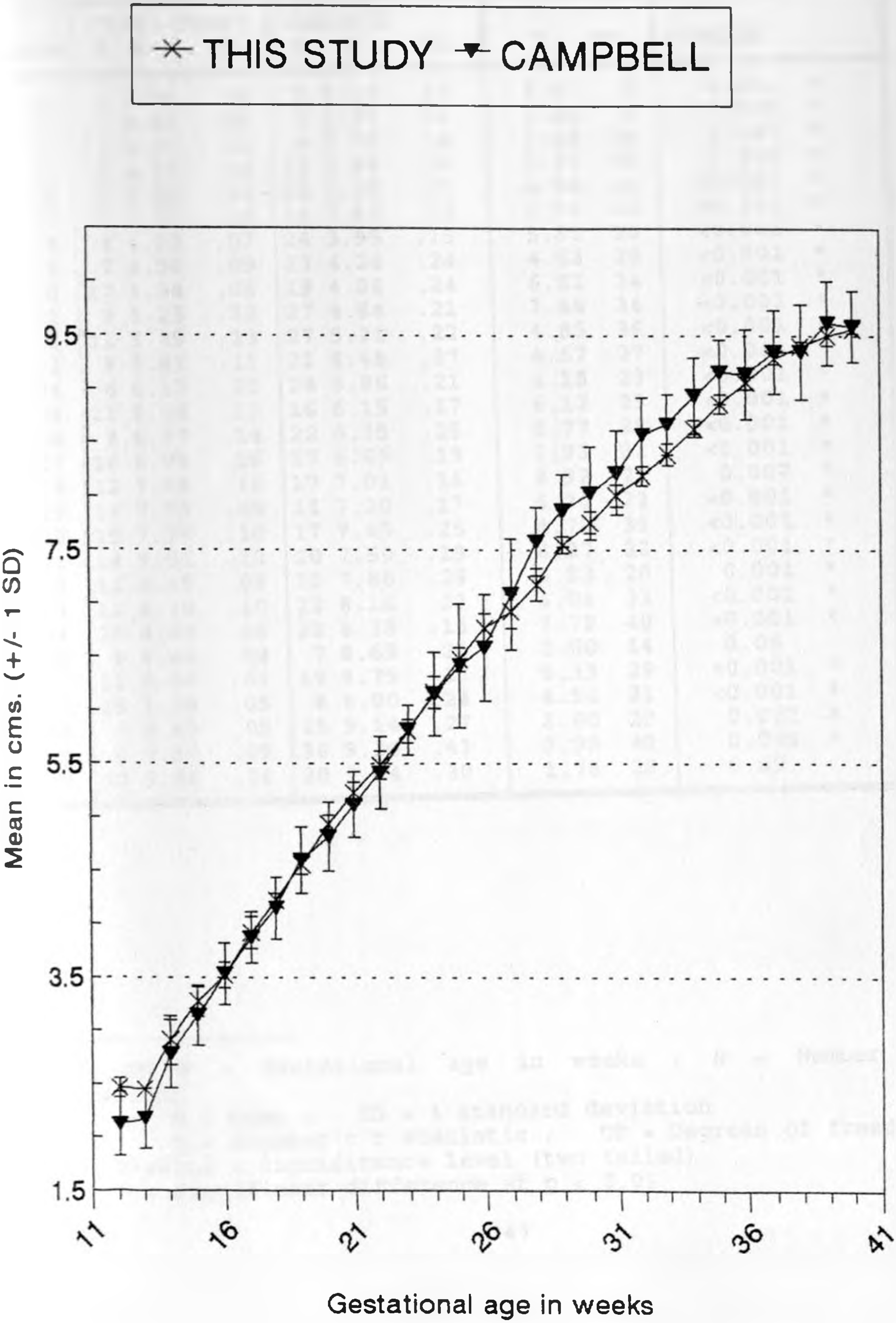


TABLE 12: DISTRIBUTION OF BIPARIETAL DIAMETER (IN CENTIMETRES) BY GESTATIONAL AGE : THIS STUDY AND HADLOCK

GESTW[2]	THIS STUDY N	M	SD	HADLOCK N	M	SD	T	DF	P-VALUE	
12	3	2.46	.09	2	2.10	.13	3.41	3	0.04	*
13	1	2.45	.00	3	2.27	.06	5.20	2	0.035	*
14	12	2.91	.23	4	2.70	.14	2.18	14	0.047	*
15	5	3.27	.14	12	2.98	.16	3.73	15	0.002	*
16	8	3.52	.12	32	3.30	.13	4.56	38	<0.001	*
17	8	3.92	.15	36	3.63	.18	4.76	42	<0.001	*
18	4	4.22	.07	24	3.95	.15	5.81	26	<0.001	*
19	7	4.56	.09	23	4.28	.24	4.63	28	<0.001	*
20	17	4.94	.08	19	4.56	.24	6.51	34	<0.001	*
21	9	5.23	.10	27	4.84	.21	7.44	34	<0.001	*
22	11	5.49	.13	27	5.21	.22	4.85	36	<0.001	*
23	8	5.81	.11	21	5.48	.27	4.67	27	<0.001	*
24	6	6.17	.15	24	5.86	.21	4.15	28	<0.001	*
25	11	6.48	.11	16	6.15	.17	6.12	25	<0.001	*
26	8	6.77	.14	22	6.35	.25	5.77	28	<0.001	*
27	16	6.93	.16	17	6.69	.19	3.93	31	<0.001	*
28	12	7.18	.15	17	7.01	.16	2.92	27	0.007	*
29	14	7.55	.08	11	7.20	.17	6.30	23	<0.001	*
30	15	7.76	.10	17	7.45	.25	4.70	30	<0.001	*
31	14	8.01	.10	20	7.59	.19	8.37	32	<0.001	*
32	12	8.19	.09	10	7.86	.26	3.83	20	0.001	*
33	12	8.39	.10	22	8.16	.23	4.04	32	<0.001	*
34	20	8.63	.08	22	8.33	.16	7.79	40	<0.001	*
35	9	8.86	.09	7	8.69	.21	2.00	14	0.06	
36	12	9.06	.06	19	8.79	.17	6.33	29	<0.001	*
37	15	9.29	.05	8	8.90	.24	4.54	21	<0.001	*
38	7	9.40	.05	15	9.14	.27	3.60	20	0.002	*
39	6	9.50	.09	36	9.26	.43	2.98	40	0.005	*
40	10	9.56	.04	20	9.44	.30	1.76	28	0.09	

[2] GESTW = Gestational age in weeks ; N = Number of observations
M = Mean ; SD = 1 standard deviation
T = Student's t statistic ; DF = Degrees of freedom
P-value = Significance level (two tailed)
* = Significant difference at $p < 0.05$

Fig 12: Distribution of biparietal diameter by gestational age

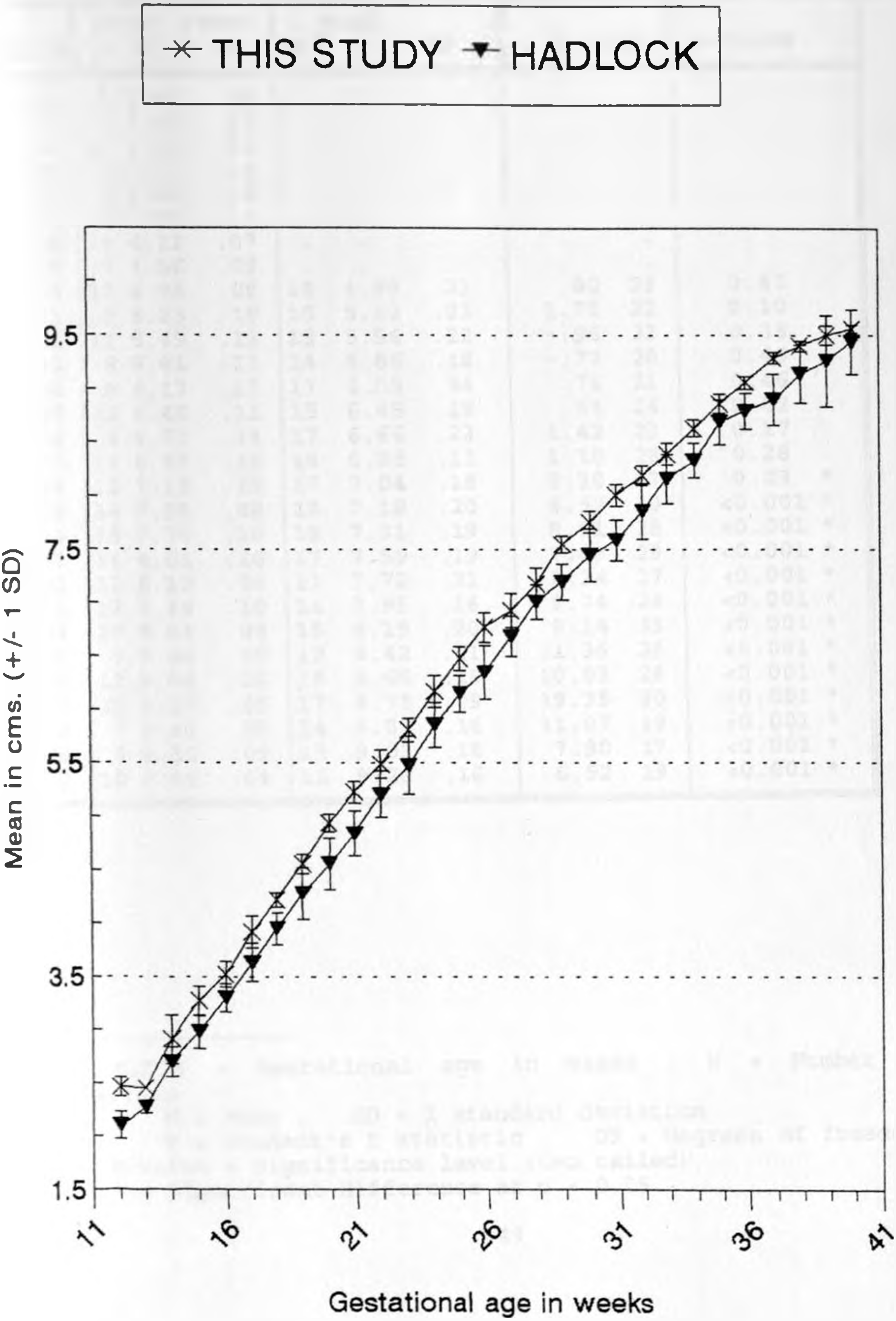


TABLE 13: DISTRIBUTION OF BIPARIETAL DIAMETER (IN CENTIMETRES) BY GESTATIONAL AGE : THIS STUDY AND ROGO

	THIS STUDY			ROGO					
GESTW	N	M	SD	N	M	SD	T	DF	P-VALUE
12	3	2.46	.09	.	.	.	.	.	
13	1	2.45	.00	.	.	.	.	.	
14	12	2.91	.23	.	.	.	.	.	
15	5	3.27	.14	.	.	.	.	.	
16	8	3.52	.12	.	.	.	.	.	
17	8	3.92	.15	.	.	.	.	.	
18	4	4.22	.07	.	.	.	.	.	
19	7	4.56	.09	.	.	.	.	.	
20	17	4.94	.08	14	4.89	.23	.80	29	0.43
21	9	5.23	.10	15	5.12	.23	1.71	22	0.10
22	11	5.49	.13	13	5.56	.22	-.96	22	0.35
23	8	5.81	.11	14	5.86	.18	-.77	20	0.45
24	6	6.17	.15	17	6.09	.34	.76	21	0.46
25	11	6.48	.11	15	6.45	.19	.51	24	0.62
26	8	6.77	.14	17	6.66	.23	1.42	23	0.17
27	16	6.93	.16	14	6.88	.11	1.10	28	0.28
28	12	7.18	.15	17	7.04	.18	2.30	27	0.03 *
29	14	7.55	.08	18	7.18	.20	6.97	30	<0.001 *
30	15	7.76	.10	15	7.31	.19	8.01	28	<0.001 *
31	14	8.01	.10	17	7.59	.19	7.88	29	<0.001 *
32	12	8.19	.09	17	7.72	.21	8.34	27	<0.001 *
33	12	8.39	.10	14	7.95	.16	8.74	24	<0.001 *
34	20	8.63	.08	15	8.19	.20	8.14	33	<0.001 *
35	9	8.86	.09	19	8.42	.11	11.36	26	<0.001 *
36	12	9.06	.06	18	8.65	.16	10.09	28	<0.001 *
37	15	9.29	.05	17	8.78	.09	19.35	30	<0.001 *
38	7	9.40	.05	14	8.89	.16	11.07	19	<0.001 *
39	6	9.50	.09	13	9.01	.18	7.90	17	<0.001 *
40	10	9.56	.04	11	9.23	.16	6.52	19	<0.001 *

[3]

[3] GESTW = Gestational age in weeks ; N = Number of observations
M = Mean ; SD = 1 standard deviation
T = Student's t statistic ; DF = Degrees of freedom
P-value = Significance level (two tailed)
* = Significant difference at $p < 0.05$

Fig 13: Distribution of biparietal diameter by gestational age

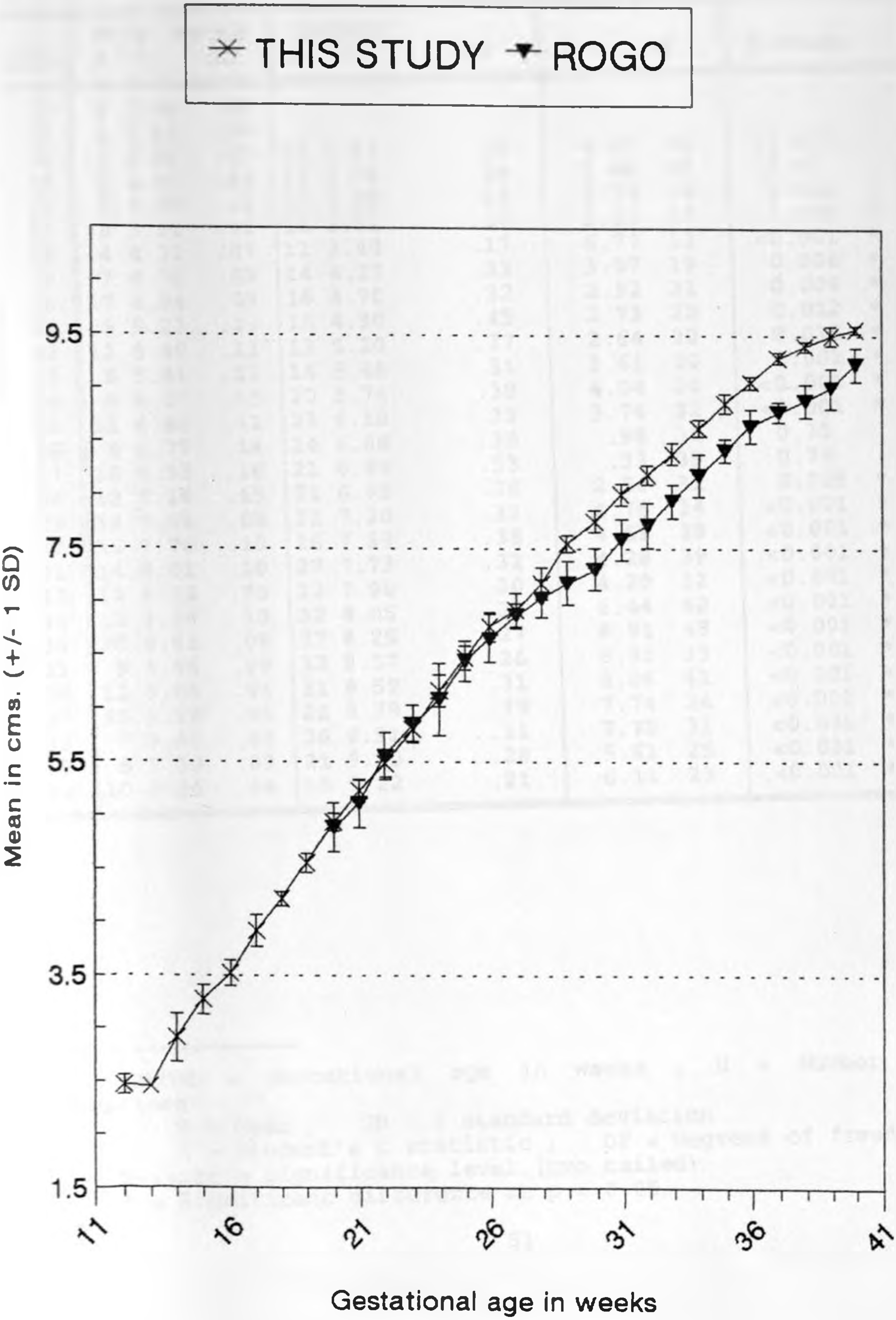


TABLE 14: DISTRIBUTION OF BIPARIETAL DIAMETER (IN CENTIMETRES) BY GESTATIONAL AGE : THIS STUDY AND QURESHI

GESTW	THIS STUDY N	M	SD	QURESHI N	M	SD	T	DF	P-VALUE
12	3	2.46	.09	.	.	.	.	.	
13	1	2.45	.00	.	.	.	.	.	
14	12	2.91	.23	11	2.44	.27	4.47	21	<0.001 *
15	5	3.27	.14	12	3.04	.24	2.46	15	0.03 *
16	8	3.52	.12	10	3.29	.23	2.73	16	0.015 *
17	8	3.92	.15	11	3.51	.37	3.32	17	0.004 *
18	4	4.22	.07	11	3.80	.17	6.77	13	<0.001 *
19	7	4.56	.09	14	4.27	.33	3.07	19	0.006 *
20	17	4.94	.08	16	4.70	.32	2.92	31	0.006 *
21	9	5.23	.10	15	4.90	.45	2.73	22	0.012 *
22	11	5.49	.13	13	5.20	.37	2.64	22	0.015 *
23	8	5.81	.11	14	5.48	.31	3.61	20	0.002 *
24	6	6.17	.15	20	5.74	.39	4.04	24	<0.001 *
25	11	6.48	.11	23	6.18	.35	3.74	32	<0.001 *
26	8	6.77	.14	24	6.68	.38	.98	30	0.33
27	16	6.93	.16	21	6.89	.53	.33	35	0.74
28	12	7.18	.15	21	6.95	.36	2.56	31	0.015 *
29	14	7.55	.08	22	7.20	.33	4.76	34	<0.001 *
30	15	7.76	.10	26	7.39	.38	4.69	39	<0.001 *
31	14	8.01	.10	27	7.73	.31	4.28	39	<0.001 *
32	12	8.19	.09	22	7.90	.30	4.20	32	<0.001 *
33	12	8.39	.10	32	8.05	.25	6.44	42	<0.001 *
34	20	8.63	.08	27	8.25	.27	6.91	45	<0.001 *
35	9	8.86	.09	32	8.37	.26	8.93	39	<0.001 *
36	12	9.06	.06	31	8.59	.31	8.06	41	<0.001 *
37	15	9.29	.05	21	8.79	.29	7.74	34	<0.001 *
38	7	9.40	.05	26	8.91	.31	7.70	31	<0.001 *
39	6	9.50	.09	21	9.10	.28	5.61	25	<0.001 *
40	10	9.56	.04	15	9.22	.21	6.11	23	<0.001 *

[4]

---

[4] GESTW = Gestational age in weeks ; N = Number of observations
M = Mean ; SD = 1 standard deviation
T = Student's t statistic ; DF = Degrees of freedom
P-value = Significance level (two tailed)
* = Significant difference at $p < 0.05$

Fig 14: Distribution of biparietal diameter by gestational age

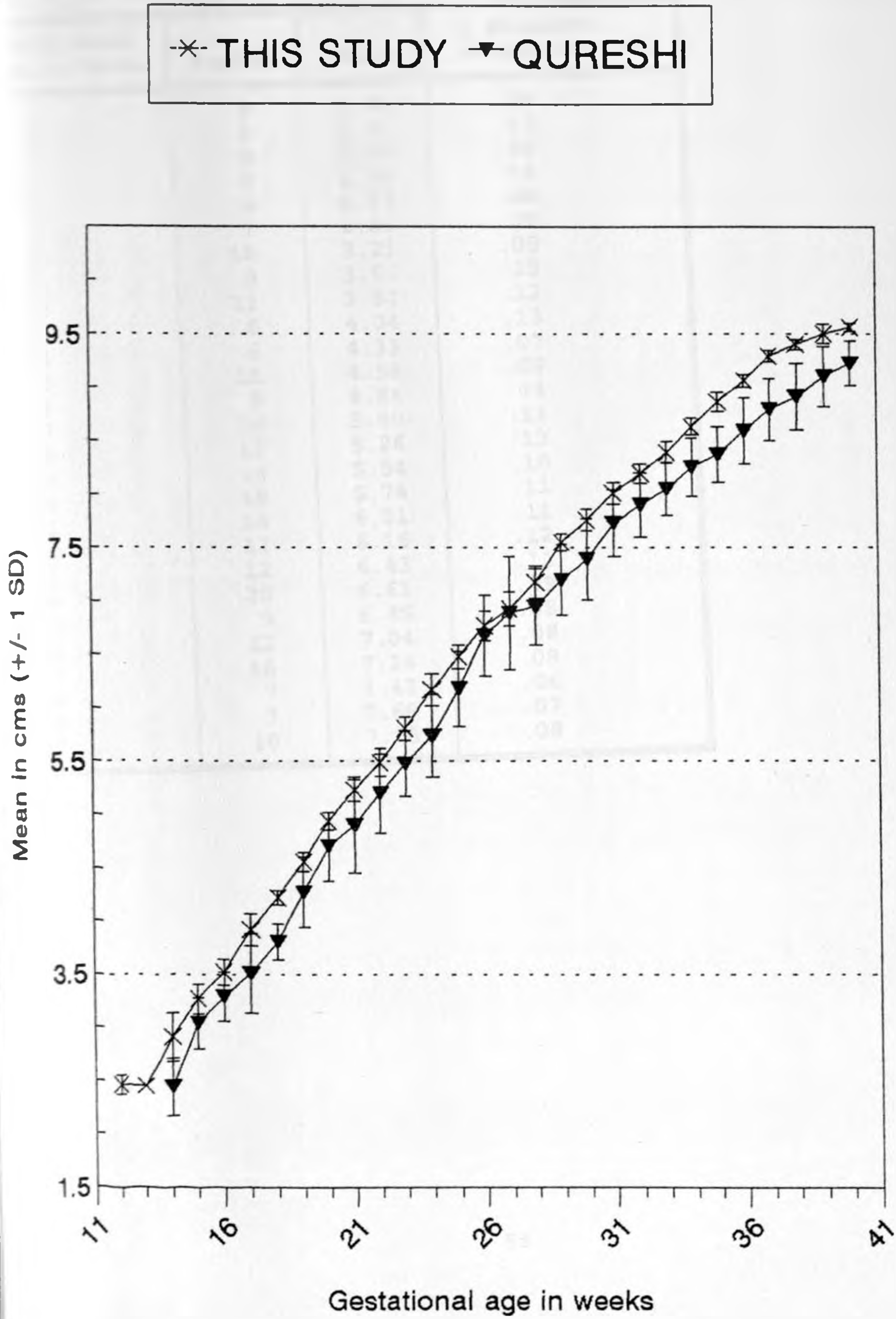


TABLE 15: DISTRIBUTION OF FEMUR LENGTH (IN CENTIMETRES) BY GESTATIONAL AGE

Gestational age in weeks	Number	Mean	1 Standard deviation (SD)
14	9	1.53	.29
15	2	1.91	.00
16	8	2.04	.08
17	8	2.38	.13
18	4	2.57	.05
19	7	2.86	.18
20	18	3.23	.09
21	9	3.56	.15
22	11	3.80	.12
23	8	4.04	.13
24	6	4.33	.07
25	11	4.58	.09
26	8	4.84	.14
27	16	5.00	.11
28	12	5.26	.13
29	14	5.54	.10
30	15	5.74	.11
31	14	6.01	.11
32	12	6.16	.12
33	12	6.43	.11
34	20	6.61	.09
35	9	6.85	.08
36	12	7.04	.08
37	16	7.26	.08
38	7	7.43	.06
39	7	7.66	.07
40	10	7.78	.08

Fig 15: Distribution of femur length by gestational age

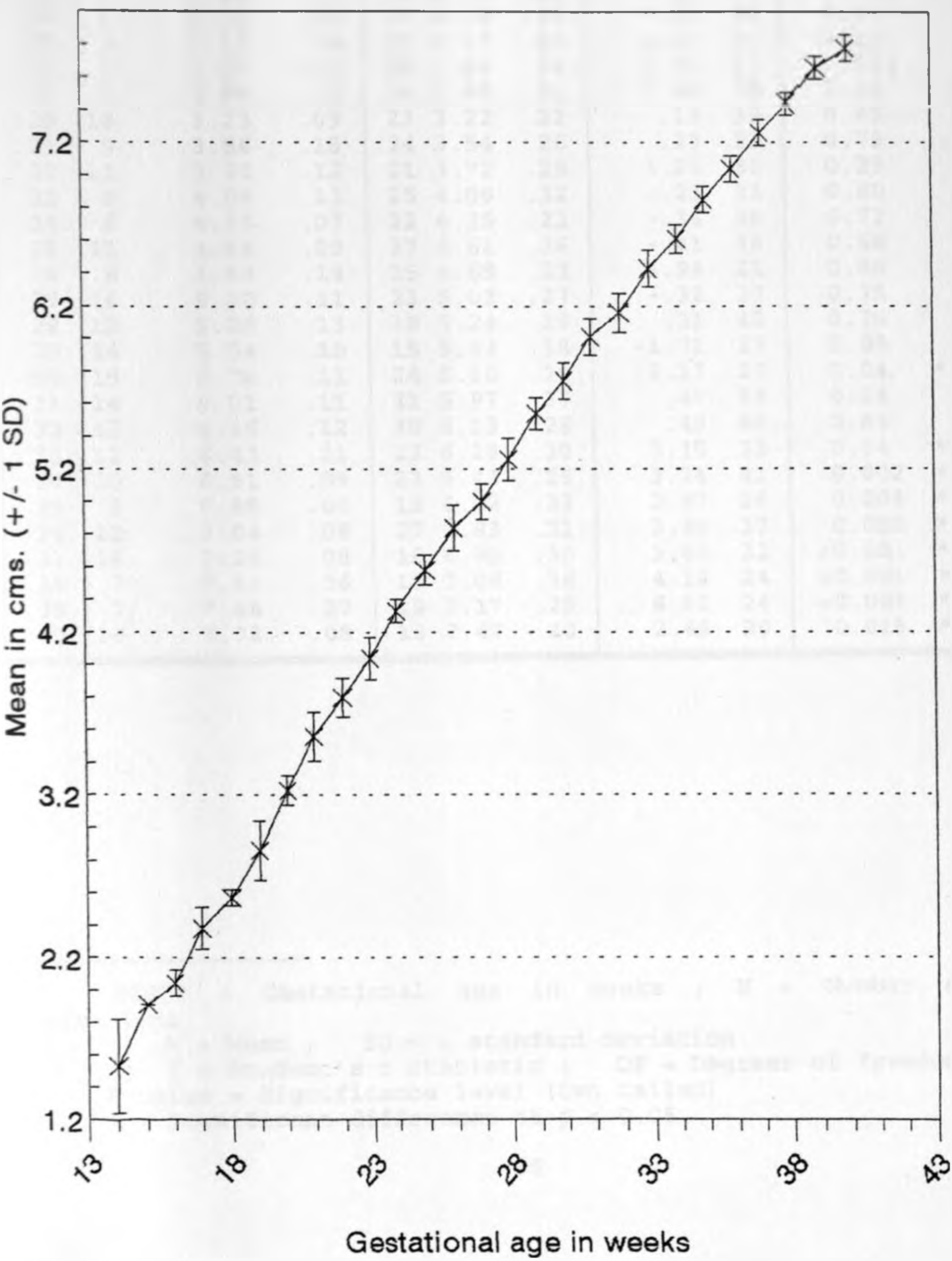


TABLE 16: DISTRIBUTION OF FEMUR LENGTH IN CENTIMETRES BY GESTATIONAL AGE : THIS STUDY AND CAMPBELL

GESTW	THIS STUDY N	M	SD	CAMPBELL N	M	SD	T	DF	P-VALUE	
14	9	1.53	.29	16	1.41	.19	1.12	23	0.27	
15	2	1.91	.00	18	1.71	.24	3.55	18	0.003	*
16	8	2.04	.08	17	2.05	.22	-.17	23	0.87	
17	8	2.38	.13	20	2.27	.22	1.63	26	0.12	
18	4	2.57	.05	25	2.69	.24	-2.25	27	0.033	*
19	7	2.86	.18	20	2.98	.21	-1.46	25	0.16	
20	18	3.23	.09	23	3.22	.22	.19	39	0.85	
21	9	3.56	.15	24	3.54	.26	.27	31	0.79	
22	11	3.80	.12	21	3.72	.25	1.23	30	0.23	
23	8	4.04	.13	25	4.06	.32	-.25	31	0.80	
24	6	4.33	.07	22	4.35	.23	-.36	26	0.72	
25	11	4.58	.09	27	4.61	.36	-.41	36	0.68	
26	8	4.84	.14	15	4.69	.22	1.98	21	0.06	
27	16	5.00	.11	23	5.02	.27	-.32	37	0.75	
28	12	5.26	.13	30	5.24	.29	.31	40	0.76	
29	14	5.54	.10	15	5.63	.18	-1.71	27	0.09	
30	15	5.74	.11	24	5.60	.29	2.13	37	0.04	*
31	14	6.01	.11	21	5.97	.37	.47	33	0.64	
32	12	6.16	.12	30	6.13	.28	.49	40	0.63	
33	12	6.43	.11	23	6.28	.30	2.15	33	0.04	*
34	20	6.61	.09	23	6.43	.25	3.24	41	0.002	*
35	9	6.85	.08	19	6.62	.33	2.87	26	0.008	*
36	12	7.04	.08	27	6.83	.31	3.30	37	0.002	*
37	16	7.26	.08	18	6.99	.30	3.65	32	<0.001	*
38	7	7.43	.06	19	7.08	.36	4.14	24	<0.001	*
39	7	7.66	.07	19	7.17	.29	6.86	24	<0.001	*
40	10	7.78	.08	12	7.47	.40	2.65	20	0.015	*

[5]

[5] GESTW = Gestational age in weeks ; N = Number of observations
M = Mean ; SD = 1 standard deviation
T = Student's t statistic ; DF = Degrees of freedom
P-value = Significance level (two tailed)
* = Significant difference at p < 0.05

Fig 16: Distribution of femur length by gestational age

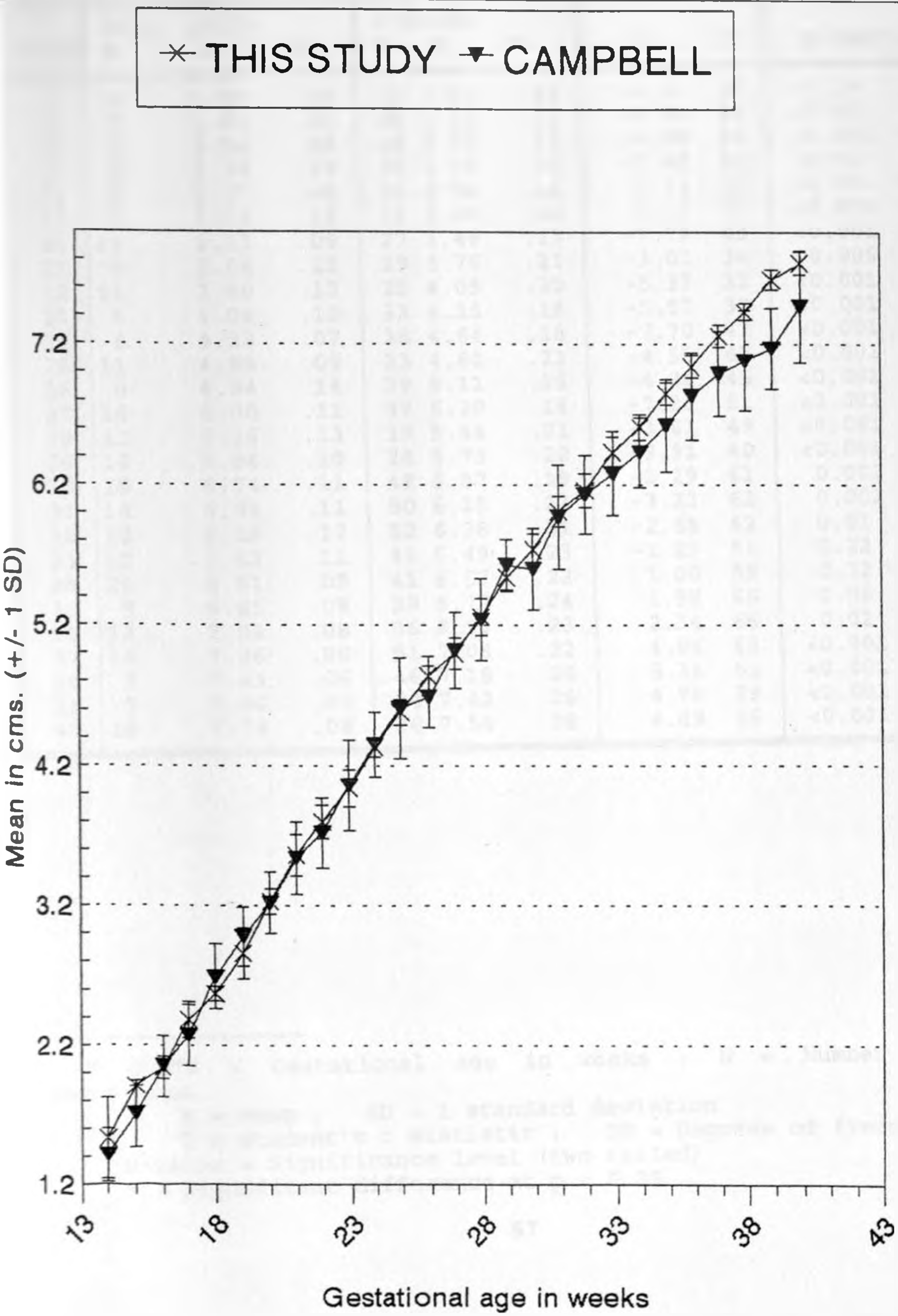


TABLE 17: DISTRIBUTION OF FEMUR LENGTH IN CENTIMETRES BY GESTATIONAL AGE : THIS STUDY AND O'BRIEN

GESTW	THIS STUDY N	M	SD	O'BRIEN N	M	SD	T	DF	P-VALUE	
14	9	1.53	.29	31	1.66	.13	-1.31	38	0.19	
15	2	1.91	.00	28	1.99	.12	-3.68	28	<0.001	*
16	8	2.04	.08	28	2.20	.15	-4.00	34	<0.001	*
17	8	2.38	.13	35	2.52	.14	-2.69	41	0.01	*
18	4	2.57	.05	30	2.96	.16	-10.33	32	<0.001	*
19	7	2.86	.18	32	3.24	.16	-5.18	37	<0.001	*
20	18	3.23	.09	27	3.48	.13	-7.79	43	<0.001	*
21	9	3.56	.15	29	3.75	.21	-3.02	36	0.005	*
22	11	3.80	.12	23	4.09	.20	-5.33	32	<0.001	*
23	8	4.04	.13	33	4.35	.18	-5.57	39	<0.001	*
24	6	4.33	.07	38	4.64	.18	-7.70	42	<0.001	*
25	11	4.58	.09	33	4.80	.23	-4.55	42	<0.001	*
26	8	4.84	.14	39	5.11	.25	-4.24	45	<0.001	*
27	16	5.00	.11	37	5.30	.16	-7.88	51	<0.001	*
28	12	5.26	.13	39	5.44	.21	-3.61	49	<0.001	*
29	14	5.54	.10	28	5.73	.22	-3.91	40	<0.001	*
30	15	5.74	.11	48	5.87	.19	-3.29	61	0.002	*
31	14	6.01	.11	50	6.15	.23	-3.23	62	0.002	*
32	12	6.16	.12	52	6.28	.21	-2.65	62	0.01	*
33	12	6.43	.11	41	6.49	.23	-1.25	51	0.22	
34	20	6.61	.09	41	6.57	.22	1.00	59	0.32	
35	9	6.85	.08	59	6.77	.24	1.95	66	0.06	
36	12	7.04	.08	56	6.95	.23	2.34	66	0.02	*
37	16	7.26	.08	51	7.08	.22	4.98	65	<0.001	*
38	7	7.43	.06	46	7.18	.28	5.31	51	<0.001	*
39	7	7.66	.07	34	7.42	.26	4.70	39	<0.001	*
40	10	7.78	.08	28	7.54	.28	4.09	36	<0.001	*

[6]

[6] GESTW = Gestational age in weeks ; N = Number of observations
M = Mean ; SD = 1 standard deviation
T = Student's t statistic ; DF = Degrees of freedom
P-value = Significance level (two tailed)
* = Significant difference at $p < 0.05$

Fig 17: Distribution of femur length by gestational age

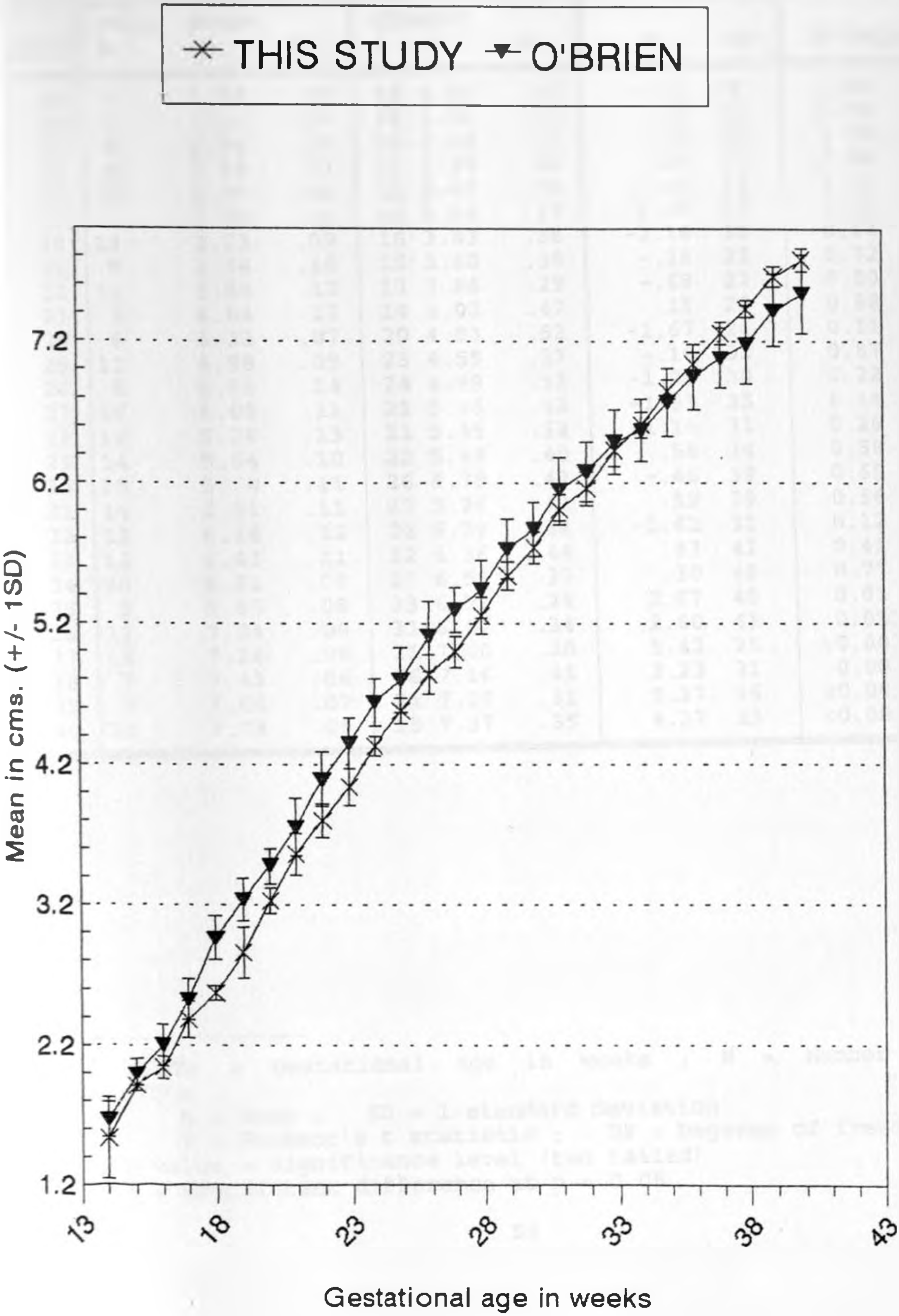


TABLE 18: DISTRIBUTION OF FEMUR LENGTH IN CENTIMETRES BY GESTATIONAL AGE : THIS STUDY AND QURESHI

GESTW	THIS STUDY N	M	SD	QURESHI N	M	SD	T	DF	P-VALUE	
14	9	1.53	.29	11	1.55	.15	-.19	18	0.85	
15	2	1.91	.00	12	1.96	.25	-.69	12	0.50	
16	8	2.04	.08	10	2.08	.16	-.69	16	0.50	
17	8	2.38	.13	11	2.35	.44	.21	17	0.84	
18	4	2.57	.05	11	2.65	.30	-.85	13	0.41	
19	7	2.86	.18	14	3.04	.37	-1.50	19	0.15	
20	18	3.23	.09	16	3.43	.36	-2.16	32	0.04	*
21	9	3.56	.15	15	3.60	.38	-.36	22	0.72	
22	11	3.80	.12	13	3.86	.29	-.68	22	0.50	
23	8	4.04	.13	14	4.02	.47	.15	20	0.88	
24	6	4.33	.07	20	4.53	.52	-1.67	24	0.11	
25	11	4.58	.09	23	4.59	.27	-.16	32	0.87	
26	8	4.84	.14	24	4.99	.53	-1.26	30	0.22	
27	16	5.00	.11	21	5.15	.43	-1.53	35	0.14	
28	12	5.26	.13	21	5.35	.32	-1.14	31	0.26	
29	14	5.54	.10	22	5.49	.40	.56	34	0.58	
30	15	5.74	.11	26	5.78	.42	-.46	39	0.65	
31	14	6.01	.11	27	5.96	.41	.59	39	0.56	
32	12	6.16	.12	22	6.29	.34	-1.62	32	0.12	
33	12	6.43	.11	32	6.36	.44	.83	42	0.41	
34	20	6.61	.09	27	6.59	.33	.30	45	0.77	
35	9	6.85	.08	33	6.71	.26	2.67	40	0.01	*
36	12	7.04	.08	31	6.87	.34	2.60	41	0.013	*
37	16	7.26	.08	21	7.00	.20	5.42	35	<0.001	*
38	7	7.43	.06	26	7.16	.41	3.23	31	0.003	*
39	7	7.66	.07	21	7.27	.31	5.37	26	<0.001	*
40	10	7.78	.08	15	7.37	.35	4.37	23	<0.001	*

[7]

[7] GESTW = Gestational age in weeks ; N = Number of observations
M = Mean ; SD = 1 standard deviation
T = Student's t statistic ; DF = Degrees of freedom
P-value = Significance level (two tailed)
* = Significant difference at $p < 0.05$

Fig 18: Distribution of femur length by gestational age

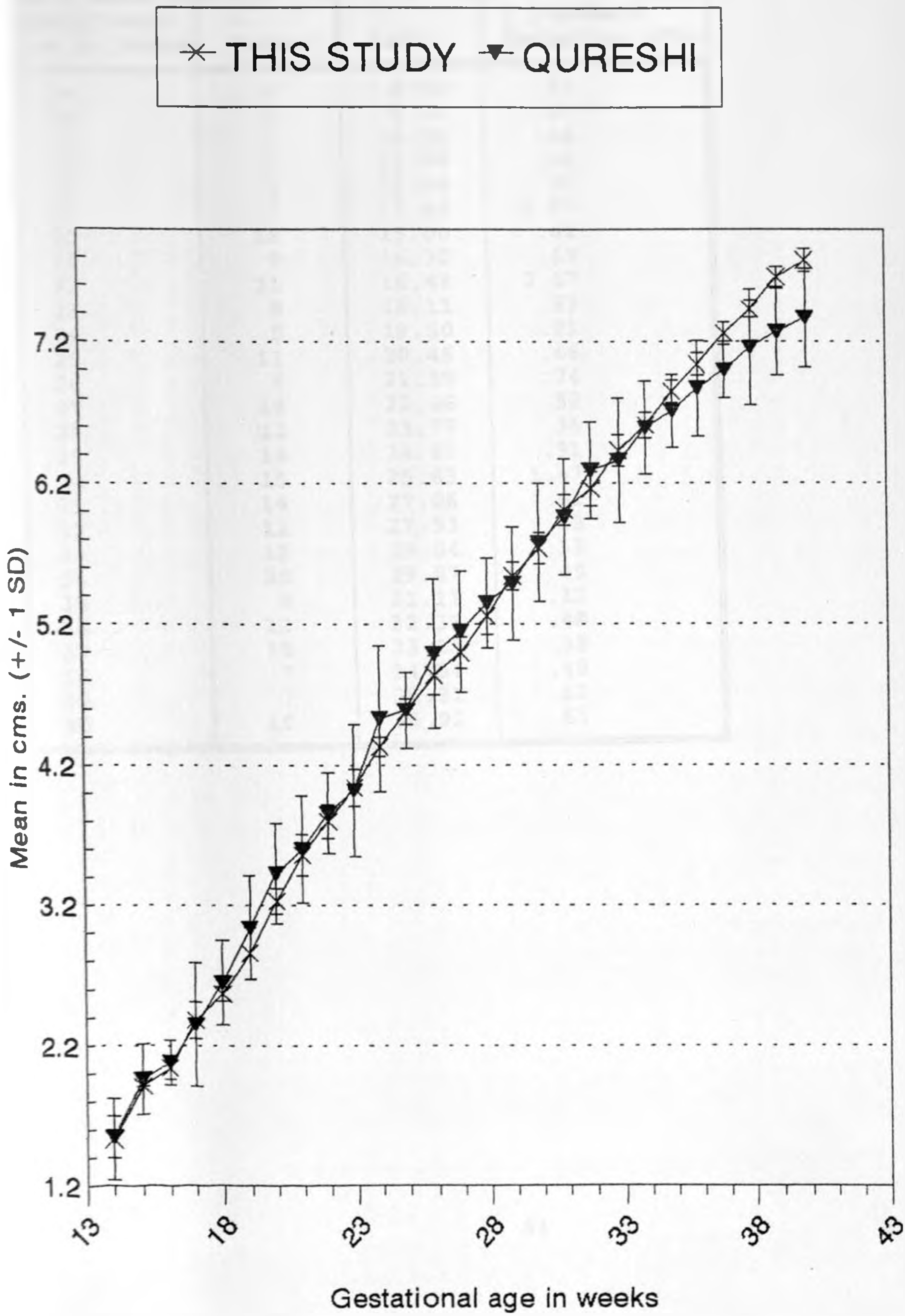


TABLE 19: DISTRIBUTION OF ABDOMINAL CIRCUMFERENCE (IN CENTIMETRES) BY GESTATIONAL AGE

Gestational age in weeks	Number	Mean	1 Standard deviation (SD)
14	9	8.58	.01
15	2	9.74	.00
16	7	10.15	.34
17	8	11.64	.46
18	4	12.58	.37
19	7	11.88	3.87
20	18	15.00	.62
21	9	16.30	.69
22	11	16.48	2.07
23	8	18.11	.53
24	5	19.50	.21
25	11	20.45	.46
26	8	21.59	.74
27	16	22.46	.52
28	12	23.77	.36
29	14	24.67	.91
30	15	25.63	1.47
31	14	27.06	.61
32	12	27.93	.53
33	12	29.04	.53
34	20	29.87	.49
35	9	31.11	.32
36	12	32.35	.48
37	15	33.19	.38
38	7	34.04	.49
39	7	35.31	.51
40	10	35.92	.63

Fig 19: Distribution of abdominal circumference by gestational age

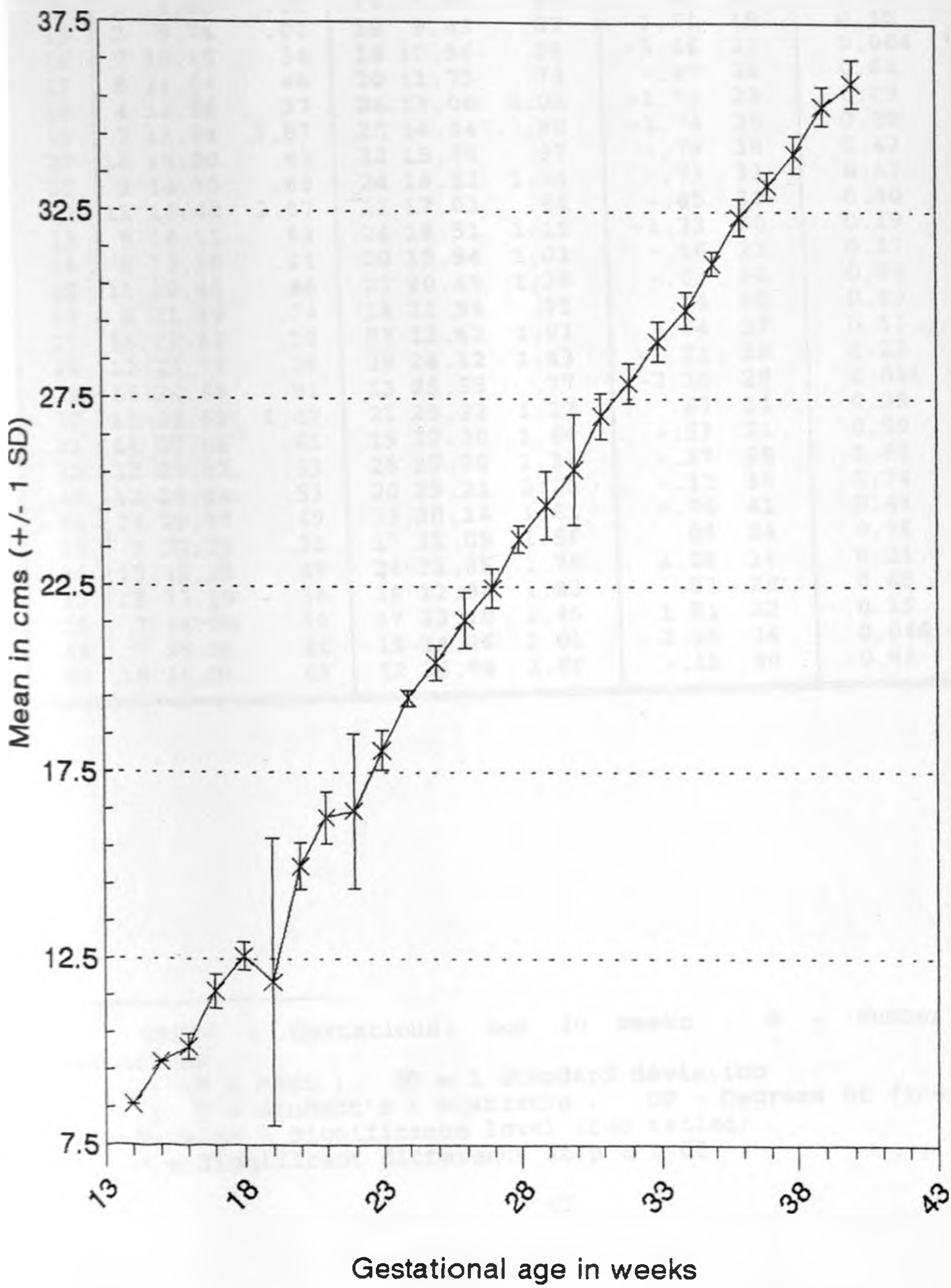


TABLE 20: DISTRIBUTION OF ABDOMINAL CIRCUMFERENCE IN CENTIMETRES BY GESTATIONAL AGE : THIS STUDY AND CAMPBELL

GESTW[a]	THIS STUDY N	M	SD	CAMPBELL N	M	SD	T	DF	P-VALUE
14	9	8.58	.01	16	8.46	.80	.60	23	0.55
15	2	9.74	.00	18	9.43	.87	1.51	18	0.15
16	7	10.15	.34	18	10.96	.94	-3.16	23	0.004 *
17	8	11.64	.46	20	11.75	.74	-.47	26	0.64
18	4	12.58	.37	26	13.06	1.05	-1.73	28	0.09
19	7	11.88	3.87	20	14.44	.80	-1.74	25	0.09
20	18	15.00	.62	22	15.20	.97	-.79	38	0.43
21	9	16.30	.69	24	16.53	1.04	-.73	31	0.47
22	11	16.48	2.07	21	17.03	.84	-.85	30	0.40
23	8	18.11	.53	24	18.51	1.15	-1.33	30	0.19
24	5	19.50	.21	20	19.54	1.01	-.16	23	0.87
25	11	20.45	.46	27	20.46	1.35	-.03	36	0.98
26	8	21.59	.74	14	21.54	.95	.14	20	0.89
27	16	22.46	.52	23	22.62	1.03	-.64	37	0.53
28	12	23.77	.36	28	24.12	1.43	-1.21	38	0.23
29	14	24.67	.91	13	25.35	.77	-2.10	25	0.046 *
30	15	25.63	1.47	21	25.22	1.27	.87	34	0.39
31	14	27.06	.61	19	27.30	1.84	-.53	31	0.59
32	12	27.93	.53	25	27.98	1.24	-.17	35	0.86
33	12	29.04	.53	20	29.21	2.20	-.33	30	0.74
34	20	29.87	.49	23	30.14	1.61	-.76	41	0.45
35	9	31.11	.32	17	31.09	1.56	.05	24	0.96
36	12	32.35	.48	24	31.85	1.79	1.28	34	0.21
37	15	33.19	.38	16	32.94	1.83	.53	29	0.60
38	7	34.04	.49	17	33.10	2.45	1.51	22	0.15
39	7	35.31	.51	19	34.26	2.01	2.10	24	0.046 *
40	10	35.92	.63	12	36.04	2.66	-.15	20	0.88

[a] GESTW = Gestational age in weeks ; N = Number of observations
M = Mean ; SD = 1 standard deviation
T = Student's t statistic ; DF = Degrees of freedom
P-value = Significance level (two tailed)
* = Significant difference at $p < 0.05$

20: Distribution of abdominal circumference by gestational age

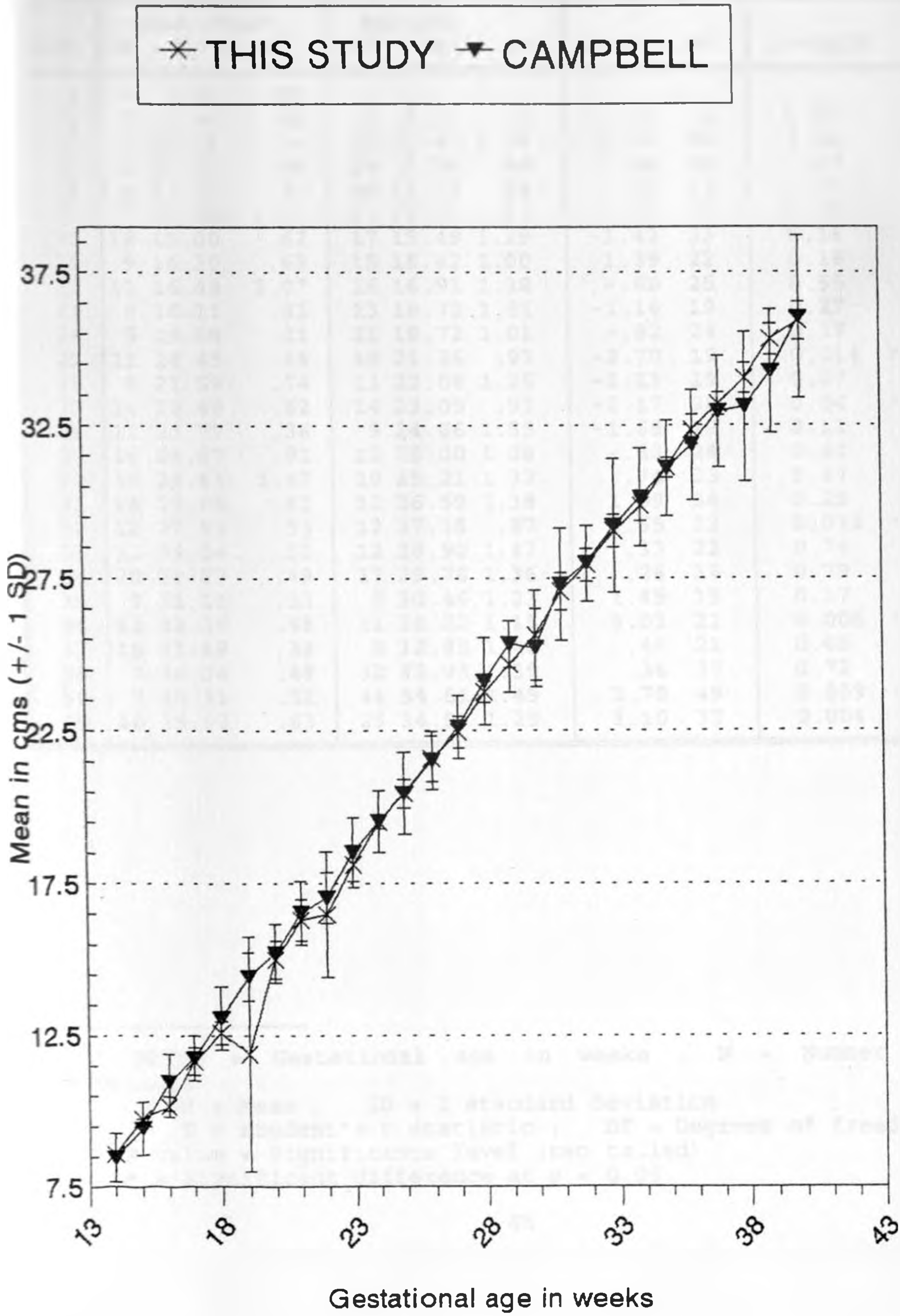


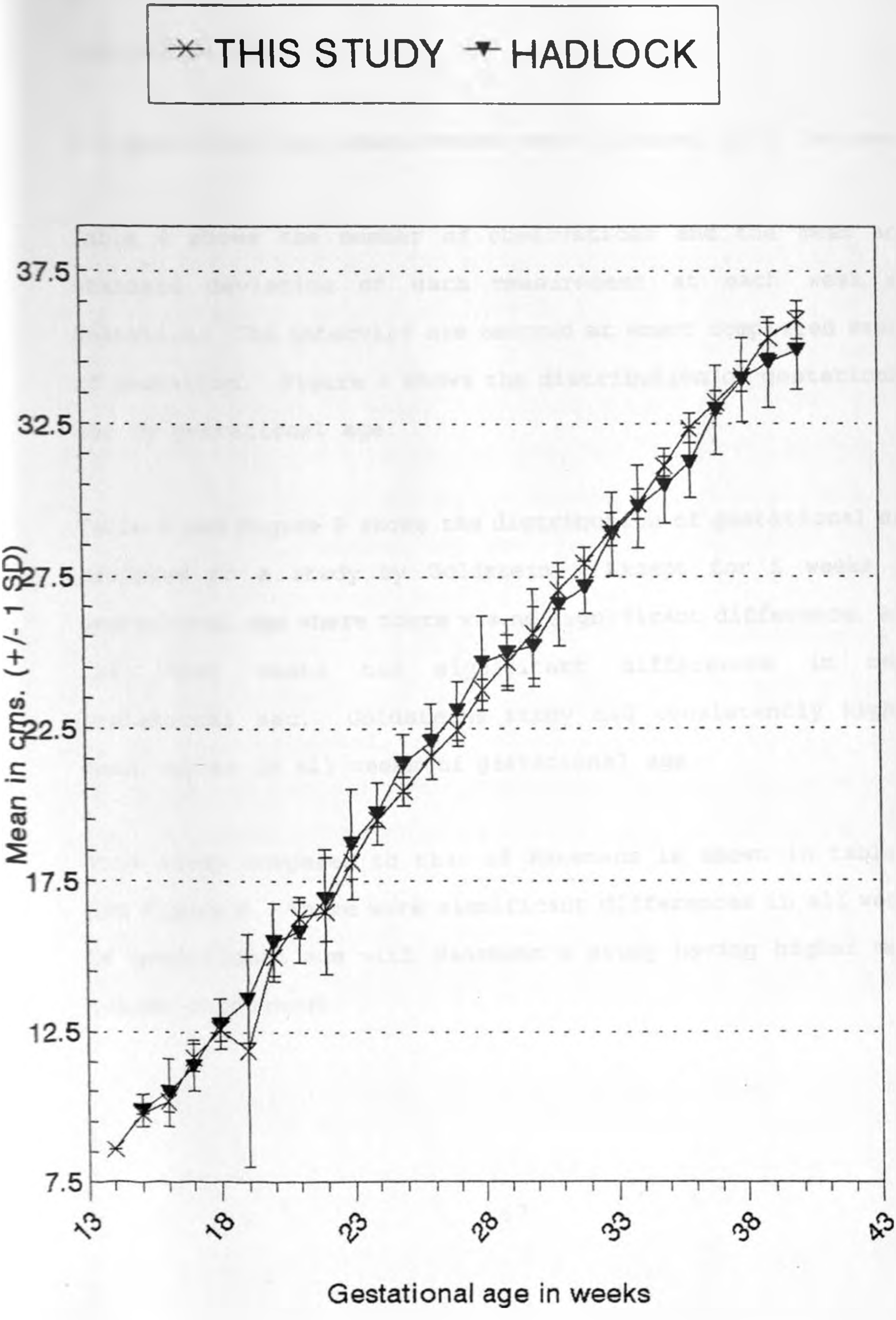
TABLE 21: DISTRIBUTION OF ABDOMINAL CIRCUMFERENCE IN CENTIMETRES BY GESTATIONAL AGE : THIS STUDY AND HADLOCK

GEST	THIS STUDY			HADLOCK					
	N	M	SD	N	M	SD	T	DF	P-VALUE
14	9	8.58	.01	.	.	.	.	.	
15	2	9.74	.00	5	9.87	.53	-.55	5	0.61
16	7	10.15	.34	15	10.47	1.14	-1.00	20	0.33
17	8	11.64	.46	18	11.36	.86	1.08	24	0.29
18	4	12.58	.37	10	12.77	.83	-.59	12	0.57
19	7	11.88	3.87	17	13.58	1.43	-1.13	22	0.27
20	18	15.00	.62	17	15.49	1.29	-1.42	33	0.16
21	9	16.30	.69	15	15.82	1.00	1.39	22	0.18
22	11	16.48	2.07	16	16.91	1.38	-.60	25	0.55
23	8	18.11	.53	13	18.72	1.81	-1.14	19	0.27
24	5	19.50	.21	21	19.72	1.01	-.92	24	0.37
25	11	20.45	.46	10	21.36	.97	-2.70	19	0.014 *
26	8	21.59	.74	13	22.08	1.25	-1.13	19	0.27
27	16	22.46	.52	14	23.09	.97	-2.17	28	0.04 *
28	12	23.77	.36	9	24.66	1.55	-1.69	19	0.11
29	14	24.67	.91	12	25.00	1.08	-.83	24	0.41
30	15	25.63	1.47	10	25.21	1.32	.74	23	0.47
31	14	27.06	.61	12	26.59	1.38	1.09	24	0.29
32	12	27.93	.53	12	27.15	.87	2.65	22	0.015 *
33	12	29.04	.53	12	28.90	1.37	.33	22	0.74
34	20	29.87	.49	17	29.78	1.36	.26	35	0.79
35	9	31.11	.32	8	30.46	1.23	1.45	15	0.17
36	12	32.35	.48	11	31.22	1.15	3.03	21	0.006 *
37	15	33.19	.38	8	32.95	1.46	.46	21	0.65
38	7	34.04	.49	32	33.93	1.39	.36	37	0.72
39	7	35.31	.51	44	34.51	1.49	2.70	49	0.009 *
40	10	35.92	.63	25	34.91	1.29	3.10	33	0.004 *

[9]

[9] GESTW = Gestational age in weeks ; N = Number of observations
M = Mean ; SD = 1 standard deviation
T = Student's t statistic ; DF = Degrees of freedom
P-value = Significance level (two tailed)
* = Significant difference at $p < 0.05$

21: Distribution of abdominal circumference by gestational age



DISCUSSION

Gestational sac

The gestational sac measurements were obtained on 51 fetuses.

Table 4 shows the number of observations and the mean and standard deviation of each measurement at each week of gestation. The intervals are centred at exact completed weeks of gestation. Figure 4 shows the distribution of gestational sac by gestational age.

Table 5 and Figure 5 shows the distribution of gestational sac compared to a study by Goldstein. Except for 5 weeks of gestational age where there was no significant difference, all the other weeks had significant differences in mean gestational sac. Goldsteins study had consistently higher mean values in all weeks of gestational age.

This study compared to that of Hansmann is shown in table 6 and figure 6. There were significant differences in all weeks of gestational age with Hansmann's study having higher mean values throughout.

Crown-rump length

The crown-rump length measurements were obtained on 71 patients.

Table 7 shows the number of observations, the mean and standard deviation of each measurement at each week of gestation. The intervals are centred at exact completed weeks of gestation. The mean crown-rump length distribution by gestational age is also shown in figure 7.

Table 8 and figure 8 shows the distribution of crown-rump length compared to a study by Campbell. There were no significant differences in mean crown-rump length in all weeks of gestational age between the two studies.

Results of this study compared to that of Drumm are shown in Table 9 and Figure 9. There was a significant difference at week 10 of gestational age. There was much variation in measurements in this study compared to that by Drumm; which shows consistently higher values.

The Bi-parietal diameter

The bi-parietal diameter measurements were obtained on 292 fetuses.

Table 10 shows the number of observations, mean and standard deviations of each measurement at each week of gestation. The intervals are centred at exact completed weeks of gestation. Figure 10 shows the distribution of bi-parietal diameter by gestational age. There is a progressive increase in the mean bi-parietal diameter from 14 to 40 weeks.

Table 11 and Figure 11 shows the distribution of bi-parietal diameter compared to a study by Campbell. Significant differences in mean bi-parietal diameter between the two studies were found from 28 to 35 weeks of gestational age where Campbell's study had consistently high mean values than this study. Although there are also significant differences at 12 and 13 weeks of gestational age between the two studies, the sample sizes for this study are too small for consideration of such significant differences. The variation of measurements going by standard deviations in Campbell's study was higher than that of this study.

Comparison of this study to that of Hadlock is shown in Table 12 and Figure 12. Despite small sample sizes in some weeks of gestational age in the two studies, it is apparent from Figure 12 that Hadlock's study had consistently higher mean values in all weeks of gestational age. To note also is the higher variation in Hadlock's study compared to this study.

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Table 13 and Figure 13 shows the distribution of mean bi-parietal diameter for this study compared to a study of Rogo. Significant differences in mean bi-parietal diameter are found from 28 weeks of gestational age onwards, with this study having higher mean values.

This study's comparison with that of Qureshi (Table 14 and Figure 14) shows significant differences in all weeks of gestational age except at 26 and 27 weeks. This study had higher values in all weeks of gestation compared to the study by Qureshi. The variation of measurement in Qureshi's study is higher than that of this study.

It is worth mentioning here, that the fetal head remains easily accessible for direct accurate scanning even in very late pregnancies in our women. In the Caucasian population, the head engages in the last weeks of pregnancy and accurate measurements may be difficult to get, as the transducer has to be manouvered to get past the pubic bones.

This could be one of the possible causes of these variations in measurement of the bi-parietal diameter and if so, our reading would be more representative of the actual measurements.

Femur length

The femur length was obtained on 285 patients.

Table 15 shows the number of observations, the mean and standard deviations of each measurement at each week of gestation. The intervals are centred at exact completed weeks of gestation. The mean femur length distribution by gestational age is also shown in Figure 15.

Table 16 and Figure 16 shows the distribution of femur length compared to a study by Campbell. Significant differences in mean femur length between the two studies were found from 33 to 40 weeks of gestational age where this study has consistently higher mean values than Campbell's. Although there are also significant differences at 15 and 18 weeks of gestational age between the two studies, the sample sizes for these studies are small. The variation of measurements of Campbell's study was higher than that of this study.

Comparison of this study to that of O'Brien is shown in Table 17 and Figure 17. Significant differences were found in all weeks of gestational age except weeks 14, 33, 34 and 35. O'Brien's study had higher mean values from week 14 to 33 while this study had higher mean values from week 34 to 40.

Table 18 and Figure 18 shows the distribution of mean femur length for this study compared to a study by Qureshi. Significant differences in mean femur length were found from 35 weeks of gestational age onwards and week 20. This study had distinctly higher mean values from week 35 to 40.
There was a lot of variation in femur length measurements in the study by Qureshi.

Abdominal circumference

The abdominal circumference measurements were obtained on 282 patients.

Table 19 shows the number of observations, the mean and standard deviation of each measurement at each week of gestation. The intervals are centred at exact completed weeks of gestation. The mean abdominal circumference distribution by gestational age is also shown in Figure 19.

Table 20 and Figure 20 shows the distribution of abdominal circumference compared to a study by Campbell. There was a significant difference at week 16, while weeks 29 and 39 had borderline significant differences in mean abdominal circumference. While Campbell's study had marked variation, this study also had marked variation in measurements in weeks 19, 22 and 30.

Comparison of this study to that of Hadlock is shown in Table 21 and Figure 21. Significant differences were found in 25, 27, 32, 39 and 40 weeks of gestational age.

Hence, this study shows consistently lower mean values compared to those carried out on Caucasian populations. These lower values could be attributed to genetic and environmental factors such as altitude. Social-economic status and literacy levels could also contribute to these differences.

On the other hand, higher bi-parietal diameter values have been observed in this study to that done at Kenyatta National Hospital by Rogo and Dhadialla.
Again, these variations could be explained by social-economic status and literacy level within the local population.

CONCLUSION

As a result of this study it has been found that differences exist between the Kenyan patients observed to those carried out on predominantly Caucasian populations.

This research carried out established notably lower mean values when compared to others commonly accepted gestational age tables used in routine obstetrical ultra-sound imaging.

It is important to take into account that this study was carried out amongst a middle class section of the population at Aga Khan Hospital. It is highly possible a study done on a wider cross-section of the population would show more substantive differences.

RECOMMENDATIONS

1) A very large scale study should be undertaken within Kenya in which normal, uncomplicated single pregnancies are scanned for gestational sac, crown-rump length, bi-parietal diameter, femur length and abdominal circumference.

2) From such a study nomograms should be prepared and used during ultra-sound scanning of obstetrical patients in Kenya.

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STUDY OF GESTATIONAL AGE PARAMETERS

Gestational Parameters by charts

NO.	AGE	RACE	PARITY	LMP	GA by dates	Gest.sac	BPD	CRL	Fem.lgth	Abd Circum