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Research Article

Head Circumference Measurement by Ultrasound and Its Efficacy In estimating the Gestational Age

Dr. Hisham Al-Hammami[1]*

Department of Obstetrics and Gynecology, Syrian Private University. Damascus, Syrian Arab Republic.

Correspondence
Hisham Al-Hammami
Department of obstetrics and gynecology, Syrian private university. Damascus, Syrian Arab Republic
h.hammami@hotmail.com

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ABSTRACT

This research aimed to determine the efficacy of Head Circumference (HC) by ultrasound in estimating the Gestational Age (GA) compared to GA by Naegele's rule using Last menstrual period (LMP) date. Materials and Methods: This was a prospective observational study of women with a normal spontaneously conceived viable singleton pregnancy, a regular menstrual cycles, and spontaneous onset of labor at term. The LMP was considered certain in all cases. We used ultrasound to scan 2067 fetuses (894 healthy women) and we had 1553 Head circumference (HC) measurements. Data were collected prospectively and used for statistical analysis. We used Descriptive Statistics to calculate the Mean, Standard Deviation (SD), Median and Percentiles values (3rd, 5th, 10th, 50th, 90th, 95th, and 97th) for HC measurements on gestational age. We found a regression equation to estimate the GA using HC measurements. The results of the current study were compared with different studies using the Paired Differences (t-test analysis). These results can be useful in women who cannot recall their last menstrual period (LMP). Our criteria will provide useful references for estimating gestational age and fetal care. A larger study might be needed to include a larger sample of the population.

INTRODUCTION

Monitoring fetal growth and assessing the growth predictors has an important role in the care of pregnant women. Accurate estimation of GA gestational age and Fetal Weight (FW) are clinically important. Ultrasound is useful as an accurate method for estimating Gestational Age (GA). Different embryonic measurements can be used to date pregnancy. Accurate estimation of GA is important in for normal and pathological pregnancies management. [1, 2, 3] We used HC to predict the GA in pregnant women reviewing ALTAWLID Hospital. Up to our Knowledge, this study is the first of its kind in Syria.

MATERIALS AND METHODS

1- Study design: This study is a prospective descriptive longitudinal population study.

2- Setting: ALTAWLID University Hospital

3- Description of populations and variables: All the participants were pregnant women representing a specific geographic region from Damascus and its suburbs, who reviewed the hospital either to confirm pregnancy or for following up. 51% (455/894) of all participants were between 22-30 years old and most of them were housewives of a low socioeconomic status.

4- Inclusion criteria:

- Voluntary participation with informed consent.
- A correct, accurate and reliable patient's knowledge of the first day of the LMP.
- Regular menstrual cycles (at least three previous regular menses).
- Singular alive normal fetus with a gestational age between 13-41 weeks. [3].
- Spontaneous labor by full term pregnancy (259-293 days/37-41 weeks).

5- Exclusion criteria: Women who have one of the following:

- Uncertainty of the LMP date.
- Irregular menstrual cycles.
- Multi-gestation or fetal demise.
- Oral contraceptive use (OCP) or any recent hormonal treatment (3-4 months) before current pregnancy.
- Pregnancy during lactation.
- History of previous abortion or recent delivery preceding the current pregnancy.
- Diagnosis of fetal malformations during examination or after birth.
- Presence of any medical or obstetric complication with known effect on fetal growth.
- Smoking or drug addiction.

- HC measures taken after week 41 of pregnancy.
- Pregnancies that ended in abortion preterm or post term deliveries.
- Date of delivery (vaginal or cesarean section) is inaccurate.
- Mal positioned deliveries.

6- Ultrasound examination: An ultrasound examination was made for 894 pregnant women (2067 fetuses) who were selected according to the previously explained inclusion and exclusion criteria and reviewed the hospital between January 2017 and August 2017 to determine gestational age by measuring different fetal parameters (in this study HC). We had 1553 HC measurements.

STATISTICAL ANALYSIS METHODS

The regression model of the HC was used to determine the GA and in order to choose the best regression model we used the: 1- Coefficient of Determination (r^2) and the adjusted Coefficient of Determination ($\overline{r^2}$) and chose the one with the higher value. 2- The standard error (Std.Error) of both methods and chose the one least value. 3- Durbin–Watson Test and chose the one that gives a value close to the Std. Error. 4- The significance of regression model by doing an analysis of variance. 5- The significance of the regression model constants' (parameters) using T test. 6- Estimating the SD of the GA using the HC regression model. Paired – Samples T-TEST were done to test each method accuracy.

RESULTS AND DISCUSSION

Growth chart of the HC measurements of Table 1 (mm) showing the Percentile Values and Standard deviation (SD) during 11-42 weeks of pregnancy.

The Embryonic Parameters have several applications in clinical practice such as estimating the gestational age, fetal weight, and fetal growth. In this study, we presented Growth Charts & Tables with the (3rd, 5th, 10th, 50th, 90th, 95th, and 97th) Percentile Values and the standard deviation of HC during the concordant pregnancy periods. We set a regression model equation that can be used to estimate the expected GA using HC measurements (mm).This equation was statistically significant (P <0.001). A strong correlation was found between the dependent variable (GA) and the independent variable (HC). We presented charts and tables that can estimate the GA (weeks) using HC measurements (mm).

We found a third degree valuable regression equation ($p<0.001$) that we can use to get the expected GA from HC measures (mm).

GA from HC measures (mm):

$$\hat{Y}_i = 7.781 + 0.068\,(HC)_i - 6.77{*}10^{-5}\,(HC)_i^2 + 3.91{*}10^{-7}\,(HC)_i^3$$

$$\bar{r}^2 = 0.98$$

The Adjusted Coefficient of Determination $(\bar{r})^{2\ of}$ the regression model of GA (weeks) using HC measurements (mm) was 0.98. The coefficient of determination is greater than 0.75 (75%), therefore, the correlation between the dependent variable Y line (GA) and the independent variable X line (HC) is very strong (Figure 2).

The Mean Sum of Squares of regression deviations of the GA regression model using (HC) was 36737.6 and this value is significant at P <0.001.

The standard error of the Estimate (Std.Error) for the GA regression model (using HC measurements) was 1.35 (Figure 2). This value represents the effect of many factors that were not included in the regression model which affect the dependent variable Y line (GA). (Figure 2).

Figure 2 shows the expected GA (weeks) using HC measurements (mm). Based on the regression model, we also demonstrated the expected GA, the lower and upper limits of the confidence interval (Table 2).

The standard deviation (SD) of estimated the GA (weeks) from the actual GA using HC measurements (mm) were (0.8,1.0 ,, ,1.3 1.6, 1.7) weeks when the GA were (12-18, 18-24, 24-30, 30-36, 36-42), respectively. (Table 3)

We compared this study to many similar studies such as Kawin Kankeow, J. Kurmana vicious, ASUM, Hadlock, and PJ Schluter. We compared the correlation coefficient, the mean, standard deviation, standard Error, lower and upper limits of the confidence interval (95% Confidence Interval of the Difference), the T value, the degree of freedom df, P value and Statistical Significance.

The comparison results were: the correlation coefficients values were strong (0.9986, 0.9996, 0.9988, 0.99, 0.9996) and significant (0.000, 0.000, 0.000, 000, 0.000) between this study and the compared studies (Kawin Kankeow, Altman & Chitty, ASUM, PJ Schluter, Hadlock, respectively (P <0.001) (Table 4). The mean difference in the HC measurements (mm) using the Paired-Samples T-TEST between this study and the compared studies was (-4.18, -0.54, -3.85, 1.74, -0.95) mm, respectively according to GA (weeks). The negative values indicates that the values of the compared studies were

higher. There is statistical significance (P <0.001) between the current study and all the compared studies except PJ Schluter and Altman &Chitty. (Table 5, Figure 3).

CONCLUSION

Many women do not recall their LMP and most pregnant women review the clinic in the first three months of pregnancy and the estimation of GA is important for the follow up and setting the Expected delivery date (EDD) for assessing growth during the rest of pregnancy and predicting the expected date of delivery (EDD). We presented diagrams and tables for the estimation of GA using HC measurements in a group of pregnant Syrian women reviewing ALTAWLID Hospital according to the inclusion and exclusion criteria stated before. These results can be useful in women who cannot recall their last menstrual period (LMP). Our criteria will provide useful references for estimating gestational age and fetal care. A larger study might be needed to include a larger sample of the population. We also compared our results with similar studies abroad, and we found that our results were lower than their counterparts were. These results could help in estimating the gestational age, diagnosing fetuses who are younger than their GA, and IUGR embryos. Thus, ultrasound may be more accurate and could replace LMP method.

RECOMMENDATIONS

1. Emphasize the importance of doing a bigger more inclusive study to determine the accuracy of the fetal measurements in predicting the delivery date 2. Using the HC by ultrasound to determine the GA especially in women who cannot recall their LMP accurately.

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FIGURE AND TABLE

HC (mm)							Standard Deviation	GA (weeks)
%97	%95	%90	%50	%10	%5	%3	SD	
55.3	60.7	60.3	59.8	58.0	56.2	55.7	55.3	11
62.6	83.4	82.1	80.1	73.0	65.9	63.9	62.6	12
70.0	99.3	97.5	94.7	84.7	74.6	71.8	70.0	13
78.8	117.5	115.1	111.3	98.1	84.9	81.2	78.8	14
100.2	132.6	130.5	127.4	116.4	105.4	102.2	100.2	15
105.2	139.6	137.5	134.1	122.4	110.7	107.3	105.2	16
118.2	155.5	153.2	149.6	136.9	124.2	120.6	118.2	17
130.6	170.5	168.0	164.1	150.6	137.0	133.1	130.6	18
140.3	185.4	182.5	178.2	162.8	147.5	143.2	140.3	19
152.0	200.3	197.2	192.6	176.1	159.7	155.0	152.0	20
161.9	213.9	210.6	205.6	187.9	170.2	165.1	161.9	21
175.7	223.0	220.0	215.4	199.3	183.2	178.6	175.7	22
205.8	230.3	228.7	226.4	218.0	209.7	207.3	205.8	23
200.8	240.2	237.7	233.9	220.5	207.0	203.2	200.8	24
207.6	252.9	250.0	245.7	230.2	214.8	210.4	207.6	25
222.9	268.8	265.9	261.5	245.8	230.2	225.8	222.9	26
231.3	279.0	276.0	271.4	255.2	238.9	234.3	231.3	27
240.5	285.7	282.8	278.5	263.1	247.7	243.3	240.5	28
246.6	293.3	290.4	285.9	270.0	254.1	249.6	246.6	29
256.2	303.4	300.4	295.9	279.8	263.8	259.2	256.2	30
268.5	305.3	303.0	299.4	286.9	274.3	270.8	268.5	31
283.6	319.1	316.9	313.4	301.3	289.3	285.8	283.6	32
288.2	323.7	321.5	318.1	306.0	293.9	290.4	288.2	33
289.4	331.8	329.1	325.0	310.6	296.1	292.0	289.4	34
296.3	338.2	335.5	331.5	317.2	303.0	298.9	296.3	35
301.1	344.3	341.6	337.4	322.7	308.0	303.8	301.1	36
313.9	348.2	346.0	342.7	331.0	319.3	316.0	313.9	37
310.0	350.9	348.3	344.4	330.5	316.5	312.6	310.0	38
316.2	358.8	356.1	352.0	337.5	323.0	318.9	316.2	39
324.8	357.4	355.3	352.2	341.1	330.0	326.9	324.8	40
326.2	363.0	360.7	357.1	344.6	332.0	328.5	326.2	41
334.6	367.5	365.4	362.3	351.1	339.9	336.7	334.6	42

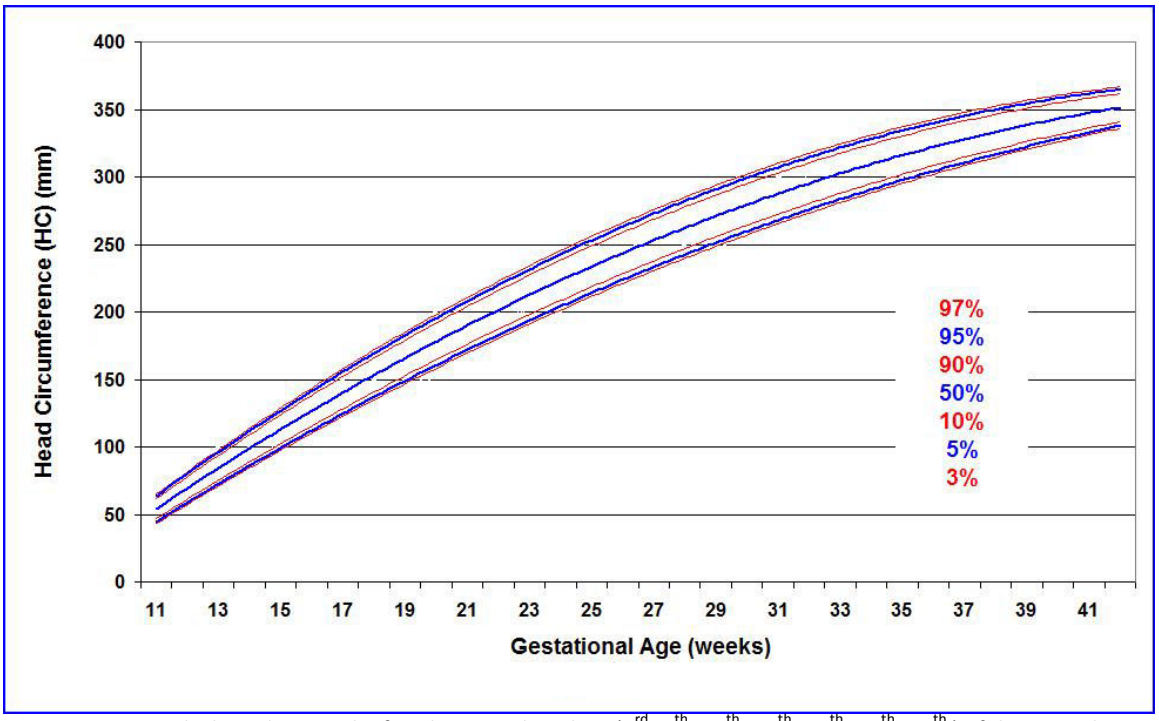

Figure 1: HC growth chart showing the fitted Percentile Values (3rd, 5th, 10th, 50th, 90th, 95th, 97th) of the HC and GA

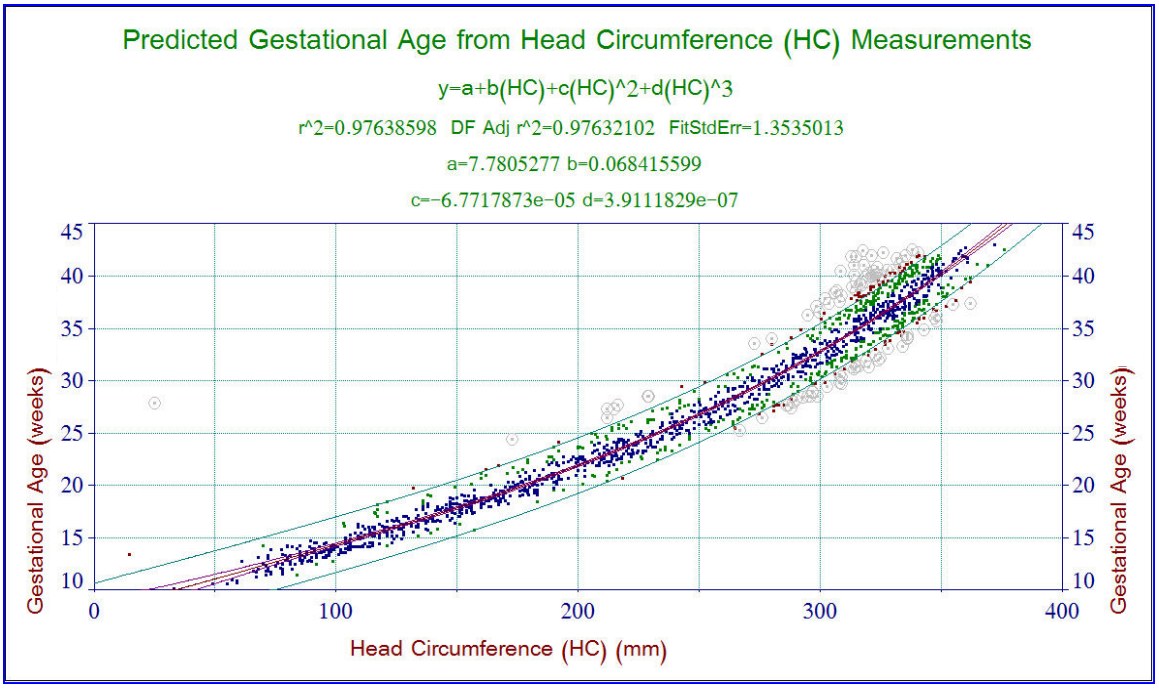

Figure 2: Predicted GA (weeks) using HC measurements (mm). Each point represents one fetus result.

Table 2: Expected GA (weeks) using the HC measurements (mm) and the lower and upper limits of both the 95% Prediction Limits and the 95% Confidence Limits based on the regression model

95%Confidence Limits		95% Prediction Limits		$\hat{Y}_i$	X_i
				GA (weeks)	HC (mm)
íUpper Limit	Lower Limit	Upper Limit	Lower Limit		
11.0	9.9	13.1	7.7	10.4	40
11.3	10.3	13.5	8.1	10.8	45
11.5	10.6	13.8	8.4	11.1	50
11.8	11.0	14.1	8.7	11.4	55
12.1	11.4	14.4	9.0	11.7	60
12.4	11.7	14.7	9.4	12.0	65
12.7	12.1	15.0	9.7	12.4	70
12.9	12.4	15.4	10.0	12.7	75
13.2	12.8	15.7	10.4	13.0	80
13.5	13.1	16.0	10.7	13.3	85
13.9	13.5	16.3	11.0	13.7	90
14.2	13.8	16.7	11.3	14.0	95
14.5	14.2	17.0	11.7	14.3	100
14.8	14.5	17.3	12.0	14.7	105
15.2	14.9	17.7	12.3	15.0	110
15.5	15.2	18.0	12.7	15.3	115
15.8	15.6	18.3	13.0	15.7	120
16.2	15.9	18.7	13.4	16.0	125
16.5	16.3	19.0	13.7	16.4	130
16.9	16.6	19.4	14.1	16.7	135
17.2	17.0	19.8	14.4	17.1	140
17.6	17.3	20.1	14.8	17.5	145
18.0	17.7	20.5	15.2	17.8	150
18.3	18.1	20.9	15.6	18.2	155
18.7	18.5	21.3	15.9	18.6	160
19.1	18.9	21.6	16.3	19.0	165
19.5	19.2	22.0	16.7	19.4	170
19.9	19.6	22.4	17.1	19.8	175
20.3	20.1	22.8	17.5	20.2	180
20.7	20.5	23.3	17.9	20.6	185
21.1	20.9	23.7	18.4	21.0	190
21.6	21.3	24.1	18.8	21.4	195
22.0	21.8	24.5	19.2	21.9	200
22.4	22.2	25.0	19.7	22.3	205

95%Confidence Limits		95% Prediction Limits		$\hat{Y}_i$	x_i
				GA (weeks)	HC (mm)
Upper Limit	Lower Limit	Upper Limit	Lower Limit		
22.9	22.7	25.4	20.1	22.8	210
23.4	23.1	25.9	20.6	23.2	215
23.8	23.6	26.4	21.1	23.7	220
25.3	25.1	27.9	22.5	25.2	235
24.3	24.1	26.9	21.5	24.2	225
24.8	24.6	27.3	22.0	24.7	230
25.3	25.1	27.9	22.5	25.2	235
25.8	25.6	28.4	23.0	25.7	240
26.3	26.1	28.9	23.6	26.2	245
26.9	26.6	29.4	24.1	26.8	250
27.4	27.2	30.0	24.7	27.3	255
28.0	27.7	30.5	25.2	27.9	260
28.6	28.3	31.1	25.8	28.4	265
29.1	28.9	31.7	26.4	29.0	270
29.7	29.5	32.3	26.9	29.6	275
30.3	30.1	32.9	27.6	30.2	280
30.9	30.7	33.5	28.2	30.8	285
31.6	31.4	34.1	28.8	31.5	290
32.2	32.0	34.8	29.5	32.1	295
32.9	32.7	35.4	30.1	32.8	300
33.5	33.3	36.1	30.8	33.4	305
34.2	34.0	36.8	31.5	34.1	310
34.9	34.7	37.5	32.2	34.8	315
35.7	35.5	38.2	32.9	35.6	320
36.4	36.2	38.9	33.6	36.3	325
37.2	36.9	39.7	34.4	37.0	330
37.9	37.7	40.5	35.1	37.8	335
38.7	38.4	41.2	35.9	38.6	340
39.5	39.2	42.0	36.7	39.4	345
40.4	40.0	42.9	37.5	40.2	350
41.2	40.8	43.7	38.4	41.0	355
42.1	41.6	44.5	39.2	41.9	360
43.0	42.5	45.4	40.1	42.7	365

95% Confidence Limits		**95%** Prediction **Limits**		$\hat{Y}_i$	**Xi**
Upper limit	**Lower limit**	**Upper limit**	**Lower limit**	**GA (weeks)**	**HC (mm)**
5.7	5.3	6.9	4.0	5.5	5
5.7	5.4	7.0	4.1	5.5	6
5.8	5.5	7.1	4.2	5.6	7
5.8	5.6	7.2	4.2	5.7	8
5.9	5.7	7.2	4.3	5.8	9
6.0	5.8	7.3	4.4	5.9	10
6.1	5.9	7.4	4.5	6.0	11
6.2	6.0	7.5	4.6	6.1	12
6.3	6.1	7.6	4.7	6.2	13
6.4	6.2	7.7	4.8	6.3	14
6.5	6.3	7.8	4.9	6.4	15
6.6	6.4	8.0	5.0	6.5	16
6.7	6.5	8.1	5.1	6.6	17
6.8	6.6	8.2	5.3	6.7	18
6.9	6.7	8.3	5.4	6.8	19
7.1	6.9	8.4	5.5	7.0	20
7.2	7.0	8.5	5.6	7.1	21
7.3	7.1	8.7	5.7	7.2	22
7.4	7.2	8.8	5.9	7.3	23
7.6	7.4	8.9	6.0	7.5	24
7.7	7.5	9.1	6.1	7.6	25
7.8	7.6	9.2	6.3	7.7	26
8.0	7.8	9.3	6.4	7.9	27
8.1	7.9	9.5	6.5	8.0	28
8.2	8.1	9.6	6.7	8.1	29
8.4	8.2	9.8	6.8	8.3	30
8.5	8.3	9.9	7.0	8.4	31

95% Confidence Limits		**95%** Prediction **Limits**		$\hat{Y}_i$	**Xi**
Upper limit	**Lower limit**	**Upper limit**	**Lower limit**	**GA (weeks)**	**HC (mm)**
8.7	8.5	10.0	7.1	8.6	32
8.8	8.6	10.2	7.3	8.7	33
9.0	8.8	10.3	7.4	8.9	34
9.1	8.9	10.5	7.6	9.0	35
9.3	9.1	10.6	7.7	9.2	36
9.4	9.2	10.8	7.9	9.3	37
9.6	9.4	10.9	8.0	9.5	38
9.7	9.5	11.1	8.2	9.6	39
9.9	9.7	11.2	8.3	9.8	40
10.0	9.8	11.4	8.5	9.9	41
10.2	10.0	11.5	8.6	10.1	42
10.3	10.1	11.7	8.8	10.2	43
10.5	10.3	11.8	8.9	10.4	44
10.6	10.4	12.0	9.1	10.5	45
10.8	10.6	12.1	9.2	10.7	46
10.9	10.7	12.3	9.4	10.8	47
11.1	10.8	12.4	9.5	11.0	48
11.2	11.0	12.6	9.7	11.1	49
11.4	11.1	12.7	9.8	11.3	50
11.5	11.3	12.9	10.0	11.4	51
11.7	11.4	13.0	10.1	11.6	52
11.8	11.6	13.2	10.2	11.7	53
12.0	11.7	13.3	10.4	11.9	54
12.1	11.8	13.5	10.5	12.0	55
12.3	12.0	13.6	10.7	12.1	56
12.4	12.1	13.7	10.8	12.3	57
12.6	12.3	13.9	11.0	12.4	58

95% Confidence Limits		**95%** Prediction **Limits**		$\hat{Y}_i$	**Xi**
Upper limit	**Lower limit**	**Upper limit**	**Lower limit**	**GA (weeks)**	**HC (mm)**
12.7	12.4	14.0	11.1	12.6	59
12.9	12.5	14.2	11.2	12.7	60
13.0	12.7	14.3	11.4	12.8	61
13.1	12.8	14.4	11.5	13.0	62
13.3	12.9	14.6	11.6	13.1	63
13.4	13.0	14.7	11.7	13.2	64
13.5	13.2	14.8	11.9	13.3	65
13.6	13.3	14.9	12.0	13.5	66
13.8	13.4	15.1	12.1	13.6	67
13.9	13.5	15.2	12.2	13.7	68
14.0	13.6	15.3	12.3	13.8	69
14.1	13.7	15.4	12.5	13.9	70
14.3	13.8	15.5	12.6	14.0	71
14.4	13.9	15.6	12.7	14.1	72
14.5	14.0	15.7	12.8	14.2	73
14.6	14.1	15.8	12.9	14.3	74
14.7	14.2	15.9	13.0	14.4	75
14.8	14.2	16.0	13.0	14.5	76
14.9	14.3	16.1	13.1	14.6	77
15.0	14.4	16.2	13.2	14.7	78
15.1	14.4	16.3	13.3	14.8	79
15.2	14.5	16.4	13.4	14.9	80
15.3	14.5	16.4	13.4	14.9	81
15.4	14.6	16.5	13.5	15.0	82
15.5	14.6	16.6	13.5	15.1	83
15.6	14.6	16.7	13.6	15.1	84
15.7	14.7	16.7	13.6	15.2	85

95% Confidence Limits		**95%** Prediction **Limits**		$\hat{Y}_i$	**Xi**
Upper limit	**Lower limit**	**Upper limit**	**Lower limit**	**GA (weeks)**	**HC (mm)**
15.8	14.7	16.8	13.7	15.2	86
15.9	14.7	16.9	13.7	15.3	87
16.0	14.7	16.9	13.7	15.3	88
16.0	14.7	17.0	13.7	15.3	89
16.1	14.6	17.0	13.7	15.4	90

Table 3: Standard Deviation (SD) of estimated the GA (weeks)

Standard Deviation	**GA (weeks)**
0.8	**18 – 12**
1.0	**24 – 18**
1.3	**30 – 24**
1.6	**36 – 30**
1.7	**42 – 36**

Table 4: Comparison between our study and reference studies:

	N	Correlation (r)	Sig.
Present Study& Kawin Kankeow [9]	27	0.9986	0.000
Present Study& (Altman & Chitty)[5,10]	31	0.9996	0.000
Present Study& ASUM [4]	31	0.9988	0.000
Present Study& PJ Schluter et al [11]	25	0.9975	0.000
Present Study& Hadlock et al [6,7,8]	29	0.9996	0.000

Table 5: Comparison of Paired Differences between our study and reference studies about predicting the GA (weeks) using HC (mm)

Statistical significant	Sig	Df	t	Paired Differences					Comparison
				95% Confidence Interval of the Difference		Std. Error / Mean	Std. Deviation	Mean	
				Upper	Lower				
Yes	0.003	26	3.33-	1.60-	6.77-	1.26	6.53	4.18-	Present Study& Kawin Kankeow [9]
No	0.301	30	1.05-	0.51	1.59-	0.52	2.87	0.54-	Present Study& (Altman & Chitty)[5,10]
Yes	0.000	30	4.69-	2.17-	5.52-	0.82	4.56	3.85-	Present Study& ASUM [4]
No	0.439	24	0.79-	1.54-	3.43-	1.20	6.02	0.95-	Present Study& PJ Schluter et al [11]
Yes	0.010	28	2.75	3.03-	0.44	0.63	3.41	1.74	Present Study& Hadlock et al [6,7,8]

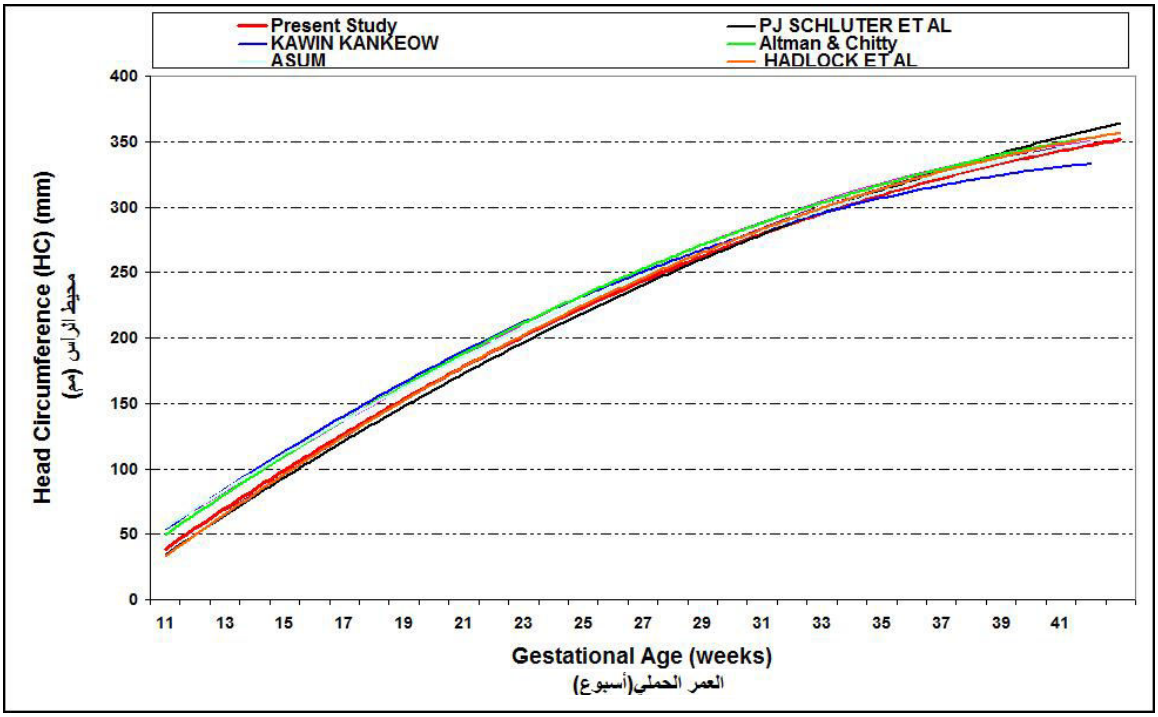

Figure 3: Comparison between GA using HC in our study (red line) and the GA using HC in reference studies (all lines except the red line)