FETAL GROWTH CHARTS FOR NORMAL PREGNANT WOMEN OF SAUDI ARABIA

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FETAL GROWTH CHARTS FOR NORMAL PREGNANT WOMEN OF SAUDI ARABIA

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

AC	Abdominal Circumference
AC.Chitty-94	AC values of Chitty et al. (1994b)
AC.Cre-00	AC values of Crequat et al. (2000)
AC.Dil-95	AC values of Dilmen et al. (1995)
AC.Dubiel-08	AC values of Dubiel et al. (2008)
AC.Fig-02	AC values of Figueras et al. (2002)
AC.Hadlock-82	AC values of Hadlock et al. (1982)
AC.Jea-84	AC values of Jeanty, Cousaert & Cantraine.(1984)
AC.John-06	AC values of Johnsen et al. (2006)
AC.Lar-90	AC values of Larsen et al. (1990)
AC.Lei-Wen-98	AC values of Lei et al. (1998)
AC.Mat-94	AC values of Mathai et al. (1994)
AC.Merz-91	AC values of Merz et al. (1991)
AC.Mon-98	AC values of Mongelli et al. (1998)
AC.Nisbet-01	AC values of Nisbet et al. (2001)
AC.Park-95	AC values of Park et al. (1995)
AC.Ramzun-09	AC values of Ramzun M R. (2009)
AC.Shin-96	AC values of Shinozuka et al. (1996)
ACE	Angiotensin Converting Enzyme
AD	Abdominal Diameter
ANC	Antenatal Care
BA	Basophils absolute
BA%	Basophils percent
BMI	Body Mass Index
BP	Blood Pressure
BPD	Biparietal Diameter
BPD.Ashraf-03	BPD values of Ashrafunnisa et al. (2003)
BPD.Bei-Zar-00	BPD values of Beigi & Zarrinkoub. (2000)
BPD.Chitty-94	BPD values of Chitty et al. (1994a)
BPD.Cre-00	BPD values of Crequat et al. (2000)
BPD.Dil-95	BPD values of Dilmen et al. (1995)
BPD.Fig-02	BPD values of Figueras et al. (2002)
BPD.Hadlock-90	BPD values of Hadlock et al. (1990)
BPD.John-06	BPD values of Johnsen et al. (2006)
BPD.Kawin-07	BPD values of KanKew et al. (2007)
BPD.Lei-Wen-98	BPD values of Lei et al. (1998)
BPD.Mat-95	BPD values of Mathai et al. (1995)
BPD.Merz-Wel-96	BPD values of Mrez&Wellek. (1996)
BPD.Mun-88	BPD values of Munjaja et al. (1988)
BPD.Nisbet-01	BPD values of Nisbet et al. (2001)
BPD.Park-95	BPD values of Park et al. (1995)
BPD.Ramzun-09	BPD values of Ramzun M R. (2009)
BPD.Rog-84	BPD values of Rogo et al. (1984)

BPD.Shin-96	BPD values of Shinozuka et al. (1996)
BW	Baby Weight
CBC	Complete Blood Count
CDP	Cephalopelvic Disproportion
CHD	Coronary Heart Disease
CI	Cephalic Index
CRL	Crown-Rump Length
CRL.Hadlock-92	CRL values of Hadlock et al. (1992)
CRL.Hansm-86	CRL values of Hansmann et al. (1986)
CRL.Kus-92	CRL values of Kustermann et al. (1992)
CRL.Las-93	CRL values of Lasser et al. (1993)
CRL.Nisbet-2003	CRL values of Nisbet et al. (2003)
CRL.Park-95	CRL values of Park et al. (1995)
CRL.Parker-82	CRL values of Parker et al. (1982)
CRL.Ramzun-09	CRL values of Ramzun M R. (2009)
CRL.Rem-91	CRL values of Rempen et al. (1991)
CRL.Robin-75	CRL values of Robinson &Fleming. (1975)
CRL.Shino-96	CRL values of Shinozuka et al. (1996)
CS	Cesarean Section
CVP	Central Venous Pressure
Dias	Diastolic Pressure
EDD	Estimated Due Date
EFW	Estimated Fetal Weight
EFW.Bog-99	EFW values of Van Bogaert et al. (1999)
EFW.Dou-97	EFW values of Doubilet et al. (1997)
EFW.Hadlock-91	EFW values of Hadlock et al. (1991)
EFW.Han-86	EFW values of Hansmann et al. (1986)
EFW.Hon-01	EFW values of Honarvar et al. (2001)
EFW.Jea-84	EFW values of Jeanty et al. (1984a)
EFW.Ramz-09	EFW values of Ramzun M R. (2009)
EFW.Shin-94-Female-multipara	EFW values of Shinozuka et al. (1994) for female with multipara
EFW.Shin-94-Female-primipara	EFW values of Shinozuka et al. (1994) for female with primipara
EFW.Shin-94-Male-multipara],	EFW values of Shinozuka et al. (1994) for male with multipara
EFW.Shin-94-Male-primipara	EFW values of Shinozuka et al. (1994) for all male with primipara
EO#	Eosinophils absolute
EO%	Eosinophils percent
Eq. no.	Equation Number
FL	Femur Length
FGR	Fetal Growth Restriction
FL.Ashraf-03	FL values of Ashrafunnisa et al. (2003)
FL.Bei-Zar-00	FL values of Beigi & Zarrinkoub. (2000)
FL.Chit-Alt-02	FL values of Chitty & Altman. (2002)

FL.Cre-00	FL values of Crequat et al. (2000)
FL.Dil-95	FL values of Dilmen et al. (1995)
FL.Fig-02	FL values of Figueras et al. (2002)
FL.Gjer-98-Black	FL values of Gjerdingen et al. (1998) of Blank
FL.Gjer-98-Caucasian	FL values of Gjerdingen et al. (1998) of Caucasian
FL.Gjer-98-Hmong	FL values of Gjerdingen et al. (1998) of ethnic Hmong
FL.Hadlock-84	FL values of Hadlock et al. (1984)
FL.Jea-84	FL values of Jeanty et al. (1984b)
FL.John-06	FL values of Johnson et al. (2006)
FL.Kawin-07	FL values of KanKew et al. (2007)
FL.Lei-Wen-98	FL values of Lei et al. (1998)
FL.Mador-12	FL values of Mador et al. (2012)
FL.Mat-95	FL values of Mathai et al. (1995)
FL.Merz-Wel-96	FL values of Merz & Wellek. (1996)
FL.Nisbet-01	FL values of Nisbet. (2001)
FL.Ram96-Indian	FL values of Raman et al. (1996) For ethnic India
FL.Ram96-Malay-Chinese	FL values of Raman et al. (1996) For ethnic Malay & Chinese
FL.Shin-96	FL values of Shinozuka et al. (1996)
GA	Gestational Age
Hb	Hemoglobin
HBP	High Blood Pressure
HC	Head Circumference
HC.Chit-94	HC values of Chitty et al. (1994a)
HC.Fig-02	HC values of Figueras et al. (2002)
HC.Hadlock-84	HC values of Hadlock et al. (1984)
HC.John-06	HC values of Johnsen et al. (2006)
HC.Merz-Wel-96	HC values of Merz & Wellek. (1996)
HC.Mun-88	HC values of Munjaja et al. (1988)
HC.Neu-04	HC values of Neufold et al. (2004)
HC.Nisbet-03	HC values of Nisbet et al. (2003)
HC.Park-95	HC values of Park et al. (1995)
HC.Ramzun-09	HC values of Ramzun M R. (2009)
HCB	Head Circumference of Baby
HCT	Hematocrit
ISUOG	International Society of Ultrasound in Obstetrics and Gynecology
IUGR	Intrauterine Growth Restriction
LB	Length of Baby
LGA	Large for Gestational Age
LMP	Last Menstrual Period
LY#	Lymphocytes absolute
LY%	Lymphocytes percentage
m	Mean value
MAP	Mean Arterial Pressure
MCH	Mean Corpuscular Hemoglobin
MCHC	Mean Corpuscular Hemoglobin Concentration

MCV	Mean Corpuscular Volume
MI	Mechanical Index
MO#	Monocytes absolute
MO%	Monocytes percentage
MPC	Mean Platelet Counts
MPV	Mean Platelet Volume
MSD	Mean Sac Diameter
N	Number
NE#	Neutrophils absolute
NE%	Neutrophils percentage
NSD	Normal Spontaneous Delivery
OFD	Occipital Frontal Diameter
OFD. Nisbat-03	OFD values of Nisbat et al. (2003)
OFD.Chit-94	OFD values of Chitty et al. (1994a)
OFD.Jeanty-84	OFD values of Jeanty et al. (1984c)
OFD.Kurmanavicius-97	OFD values of Kurmanavicius et al. (1997)
OFD.Merz-87	OFD values of Merz et al. (1987)
PLT	Platelet
PPH	Primary Postpartum Hemorrhage
PROM	Premature Rupture Of Membranes
PW	Placenta Weight
RBC	Red Blood Cells
RDW	Red cell Distribution Width
SD	Significant Difference
Std. Dev.	Standard Deviation
SGA	Small for Gestational Age
SPSS	Statistical Package for the Social Sciences
SS_M	Model Sum of Squares
SS_R	Residual Sum of the Squares
SS_T	Total Sum of Squares
SVD	Spontaneous Vaginal Delivery
SVR	Systemic Vascular Resistance
Syst	Systolic Pressure
TSH	Thyroid-Stimulating Hormone
US	Ultrasound
WBC	White Blood Cell

LIST OF SYMBOLS

µL	Microliter
Ib	Bound
bpm	Beats per min
cells/µL	Cell/ microliter
fL	Femtoliters
G	Gram
g/dL	Grams/deciliter
Hz	Hertz
kg	Kilogram
L	Liters
M	Meter
mg/dL	Milligrams/deciliter
mm	Millimeter
mmHg	Millimeter of mercury
Pg/cell	Picograms/cell
wk	Week
µm	Micrometer
kg/wk	Kilogram/week
kg/m^2	$Kilogram/meter^2$

CARTA PERTUMBUHAN FETUS BAGI WANITA HAMIL YANG NORMAL DI SAUDI ARABIA

ABSTRAK

Kajian ini bertujuan untuk mewujudkan julat rujukan baru untuk parameter biometrik janin dalam populasi Arab Saudi. Secara keseluruhan, 4075 wanita hamil yang menerima rawatan di Hospital Bersalin dan Kanak-kanak (Dammam, Arab Saudi) dan Hospital Universiti King Fahd (Khobar, Arab Saudi) telah terlibat dalam kajian ini secara retrospektif pada 2013-2015. Berdasarkan rekod dalam unit pendaftaran kedua-dua hospital, data termasuk hasil ultrasound (US) menggunakan Voluson E6 (GE Healthcare, Austria) dan Medison US SonoAce R5, dengan prob 2 hingga 5 MHz [khusus *crown–rump length* (CRL), *biparietal diameter* (BPD), *femur length* (FL), *abdominal circumference* (AC), *head circumference* (HC), *occipitofrontal diameter* (OFD), and *estimate fetal weight* (EFW)], dari 6 hingga 13 minggu kehamilan (GA) untuk CRL dan dari 12 minggu untuk BPD, 20 minggu untuk HC dan EFW, 13 minggu untuk FL, 17 minggu untuk OFD, dan 15 minggu untuk AC hingga 41 minggu kehamilan. Rawatan antenatal (ANC) (iaitu tekanan darah (BP) yang menggunakan Model CARESCAPE V100 Monitor dan Sun Tech CT40; Hemoglobin (Hb)] dari 6 hingga 41 minggu kehamilan. Analisis statistik termasuk analisis kekerapan, statistik deskriptif, perbandingan min, analisis regresi, dan uji sampel konjugasi yang dilakukan menggunakan program SPSS 22.0. Purata umur peserta ialah 29 ± 6 tahun. Analisis tekanan darah ibu hamil mendapari menunjukkan satu pertiga daripada nilai tekanan darah diastolik berada pada julat pra-tinggi (80-90 mm/Hg). Kebanyakan respondan didiagnos anemia semasa mengandung (51.16%) dan selepas melahirkan anak (80.36%). Model regresi kubik polinomial paling sesuai untuk menggambarkan hubungan antara GA dan fetus (CRL, AC, dan EFW) manakala

model kuadratik polinomial paling sesuai untuk kedua-dua parameter biometrik fetus (BPD, HC, OFD, dan FL) dan parameter ANC dengan GA dengan korelasi yang tinggi signifikan (P<0.001). Kadar pertumbuhan CRL adalah 10.22 mm/minggu sementara BPD, HC, FL dan AC menunjukkan kadar pertumbuhan yang lebih tinggi pada trimester kedua (3.17, 13.101, 2.76 dan 10.69 mm/minggu) berbanding trimester ketiga (1.65, 5.51, 1.7 dan 7.30 mm/minggu, mengikut aturan). Sebaliknya, EFW menunjukkan kadar pertumbuhan yang lebih tinggi pada trimester ketiga (161.89 g/minggu) berbanding dengan yang ketiga (120.9 g/minggu). Perbandingan parameter biometrik fetus kajian ini dengan kajian lain menunjukkan nilai HC yang ketara berbanding USA. Penurunan yang lebih ketara bagi nilai HC dan OFD (UK), OFD dan HC (USA dan UK), OFD (UK dan Switzerland), AC (Denmark), CRL (Jerman dan Eropah) manakala peningkatan yang ketara dilihat pada BPD (Iran, Turkey), FL (Iran) dan AC (Turkey), semua parameter (populasi Asia kecuali Malaysia (India etnik)). Selain itu, kajian ini mendedahkan analisis hematologi semasa kehamilan dan selepas melahirkan anak. Hasil analisis menunjukkan penurunan bilangan sel darah merah dan trombosit ketika kehamilan dan peningkatan jumlah sel darah putih yang signifikan dalam semua trimester. Oleh itu, kajian ini memberi asas maklumat bagi pertumbuhan fetus di Arab Saudi dan menjelaskan keadaan ibu dan fetus serta perubahan hemotologi semasa kehamilan di wilayah timur Arab Saudi dan mendedahkan julat perkadaron normal. Hasil kajian ini adalah penting untuk menyediakan penjagaan kesihatan yang lebih baik, dan memastikan kesihatan ibu dan fetus. Carta tumbesaran secara persentil yang terdapat dalam kajian ini amat penting bagi juru sonografi. Selain itu, keputusan ini akan membantu mengelakkan kurang anggaran atau lebih anggaran tumbesaran fetus dan dengan itu membantu mendapatkan penilaian tumbesaran fetus yang tepat.

FETAL GROWTH CHARTS FOR NORMAL PREGNANT WOMEN OF SAUDI ARABIA

ABSTRACT

This study aimed to create new reference ranges for fetal biometric parameters in the Saudi Arabian population. Overall, 4075 pregnant women who visited the Maternity and Children Hospital (Dammam, Saudi Arabia) and King Fahd University Hospital (Al Khobar, Saudi Arabia) were enrolled retrospectively during 2013–2015. Based on the records at the Record Units of both hospitals, the data including ultrasound (US) findings using Voluson E6 (GE Healthcare, Austria) and Medison US SonoAce R5 system, with a 2–5 MHz abdominal probe [namely crown–rump length (CRL), biparietal diameter (BPD), femur length (FL), abdominal circumference (AC), head circumference (HC), occipitofrontal diameter (OFD), and estimate fetal weight (EFW)] from 6th to 13th week of gestational age (GA) for CRL and from 12 weeks for BPD, 20 weeks for HC and EFW, 13 weeks for FL, 17 weeks for OFD,15 weeks for AC to 41st weeks of GA. The antenatal care (ANC) parameters [namely blood pressure (BP) used Model CARESCAPE V100 Monitor and Sun Tech CT40, hemoglobin (Hb)] were recorded from 6th to 41st week of GA. Statistical analyses comprised frequency analysis, descriptive statistics, mean comparison, regression analysis, and paired sample *t*-test was performed by using SPSS software version 22.0. Mean participant age was 29 ± 6 years. Furthermore, the analysis of maternal blood pressure during pregnancy illustrated that approximately one-third of diastolic blood pressure values were in the pre-high range (80–90 mm/Hg). Most participants were diagnosed with anemia during their pregnancy (51.16%) and postpartum (80.36%). A cubic polynomial regression model was the best-fitted to

describe the relationships between the GA and fetal (CRL, AC, and EFW) while a quadratic polynomial model was the best-fitted with both fetal biometry (BPD, HC, OFD, and FL) and ANC parameters with GA with strong significant correlations ($P<0.001$). The CRL growth rate was 10.22 mm/week while the BPD, HC, FL, and AC demonstrated a higher growth rate in the 2^{nd} trimester (3.17, 13.101, 2.76, and 10.69 mm/week, respectively) than in the 3^{rd} trimester (1.65, 5.51, 1.7, and 7.30 mm/week, respectively). In contrast, the EFW exhibited a higher growth rate in the 3^{rd} trimester (161.89 g/week) than in the 2^{nd} trimester (120.9 g/week). A comparison of fetal biometric parameters of this study with other studies revealed significant lower value for HC than the USA; HC and OFD than UK; OFD than Switzerland; AC than Denmark; CRL than German from Europe, while significant higher BPD and FL than Iran, BPD and AC than Turkey from Middle East, and higher fetal biometrics than Asian populations except for FL from Malaysian-Indian Ethnic. Moreover, this study revealed hematological analysis during pregnancy and postpartum; the results showed a decline in red blood cell and thrombocyte counts during pregnancy and a significant increase in white blood cell count in all trimesters. Thus, this study provides an informative baseline of Saudi fetal growth and illustrated the maternal and fetal condition and hematological changes during pregnancy in eastern province in Saudi Arabia and reveals the extreme normal ranges in this environment. This finding is crucial for providing better healthcare, ensuring both maternal and fetal well-being. The percentile growth charts present in this study are of great importance to all fetal sonographers. Furthermore, these findings will help avoid underestimating or overestimating fetal growth and thus help obtain accurate fetal growth assessments.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

This chapter discusses the background of this study. Besides, the problem statement related to the research work and also identified research questions. The objective, significant and scope of this study were explained with further information derived.

1.2 Study Background

Undoubtedly, pregnancy is the most critical period in any woman's life. During pregnancy, pregnant women undergo substantial anatomical and physiological changes to nurture and accommodate the developing fetus; these changes begin after conception and affect every organ system in the body (Regan, 2005). Thus, differentiating the normal physiological changes from the pathological changes for both the mother and the fetus is imperative (Regan, 2005). Typically, most clinical studies focus on monitoring changes in the maternal body and distinguishing between the normal and abnormal fetal growth. In combination with ultrasonography, fetal biometry provides the most reliable and crucial information about the fetal growth and well-being (Salomon et al., 2011).

Ultrasound (US) fetal biometry, a technique in sonographic embryology, is applied for evaluates several parts of the fetal anatomy and assesses their growth. Fetal growth is defined as the time-dependent changes in body dimensions that occur throughout pregnancy. Apparently, the growth rate of various body parts of the fetus is rapid, especially in the 1st and 2nd trimesters, as they grow significantly with the progression of pregnancy; thus, the measurements of these body parts must be assessed against the standard values at that gestational age (GA) (Hohler, 1984) (as cited in Babuta et al., 2013). Sonographic embryology is an emerging field of study that allows a detailed examination of the fetal anatomy and measurement of the unborn in utero using real-time US technology (Mador, 2011).

Fetal biometric parameters, including the crown–rump length (CRL), biparietal diameter (BPD), head circumference (HC), occipitofrontal diameter (OFD), femur length (FL), abdominal circumference (AC), and estimate fetal weight (EFW), facilitate the estimation of the GA. Notably, the determination of the GA is critical, especially for women who forget their last menstrual period (LMP) date or whose fundal height on the abdominal examination does not correspond to the dates. In contrast, at the early stage of pregnancy (6th to 7th weeks of GA), instead of the LMP date, the CRL is also used to confirm the GA. The practice of assessing the GA in early pregnancy is valuable in the detection of growth abnormalities in the later stages. Reportedly, fetal growth is characterized by a complex interaction of the genetic, maternal factors, environmental, and socioeconomic factors with normal birth patterns based on a combination of the GA at birth, head size, length, and birth weight (Vorherr, 1982).

Chitty and Altman (2002) introduced a methodological guideline for fetal biometry to perform a dependable biometric assessment. Serial measurement from each fetus is necessary for developing percentile growth curves, statistical values, such as means, standard deviations, and values at 5th and 95th percentiles that represent the lower and upper limit of the normal reference intervals, have been suggested to be evaluated for the selected parameters. The constructed scattergrams and regression analysis yields facilitate the derivation of precise regression equations that enable the prediction of the GA at specific values of fetal parameters. When the fetus assessment falls below the 5^{th} percentile curve for the corresponding GA, the fetus may be diagnosed with intrauterine growth restriction (IUGR). In addition, a sonogram (an image generated during ultrasonography) can be obtained around GA of 32–34 weeks to ascertain proper fetus growth. Thus, fetal body US reflects the normalcy of the fetus growth and detects abnormalities if any (Gardosi, 1992). In general, prenatal measurements used to estimate the fetal size and weight vary among different populations, depending on their ethnicity, demographic characteristics, and nutrition. Hence, construction of fetal biometric charts for normal fetal growth based on the local population is imperative (Shehzad et al., 2006).

Several fetal biometry studies from Iran (Honarver et al., 2000), Oman (Machado et al., 2000), Cameroon (Tagni et al., 2002), and Bangladesh (Ashrafunnisa et al., 2003) have reported different fetal parameters for their own populations, thereby enhancing the ethnic variations. Thus, a biometric chart for one population might over- or underestimate the fetal age in another population with different demographic characteristics. Thus, the construction and use of biometric nomograms for different ethnic groups are recommended (Honarvar et al., 1999).

In the last 30 years, many standard curves have been designed by many investigators to assess fetal biometry and fetal weight using US (Sletner et al., 2015; Kwon, 2014; Parikh et al., 2014; Babuta et al., 2013; Zaki et al., 2012; Ogasawara, 2009; Nasrat and Bondagji, 2005; Chitty et al., 2002; Jacquemyn et al., 2000; Kurmanavicius et al., 1999a, 1999b; Chitty et al., 1994a, 1994b, 1994c; Hadlock et al., 1991, 1982a, 1982c, 1982d). The published normal values of fetal biometry measurements have commonly depended on studies from American or Western populations (Salomon et al., 2006; Paladini et al., 2005). It is well known that the fetal biometry measurements vary across different communities and races (Rashid et al., 2012; Jacquemyn et al., 2000). However, American or Western populations differ from Asians/Middle Easterners in terms of not only their stature and size but also their socioeconomic conditions. Therefore, studies were conducted to determine whether those charts were suitable for other populations, and the results showed that they were not (Hegab et al., 2018; Sletner et al., 2015; Kwon et al., 2014; Araujo Junior et al., 2014; Zaki et al., 2012; Rashid et al., 2012). Normative values should be assessed to identify the most appropriate values for the population under study. If suitable standards cannot be found, they should be developed (Deter et al., 1983).

The determination of suitable reference charts is of considerable importance to ensure an accurate diagnosis. Saudi, as in most Middle East countries, lacks fetal size charts; hence, Saudi obstetricians rely on fetal charts included in the software of the US machines to implement fetal biometric measurements. However, these charts are derived from pregnancies of American or Anglo-Saxon populations (Nasrat and Bondagji, 2005). This practice is still adopted even though several studies have demonstrated significant ethnic variations in fetal size and growth (Sletner et al., 2015; Kwon, 2014; Parikh et al., 2014; Babuta et al., 2013; Zaki et al., 2012; Ogasawara, 2009; Nasrat and Bondagji, 2005; Jacquemyn et al., 2000; Kurmanavicius et al., 1999a, 1999b). Marked variations in fetal measurements are present among various inhabitants, particularly at the extreme ranges of fetal parameters (5th and 95th percentiles) (Nasrat and Bondagji, 2005). The clinical application of charts based on data obtained from different inhabitants could increase the risk of misdiagnosis (increase or decrease) of IUGR. It is essential to initiate native charts on fetal size during the gestational period for the purpose of perfect fetal assessments (Zaki et al., 2012).

Currently, the reference charts and equations from the Saudi population using appropriate methodology have not previously been published in the open literature. To the best of the researcher's knowledge, this study is the first study in the literature to report all common fetal charts using Saudi fetal biometry, particularly from Dammam city. Therefore, the primary purpose of this study was to explore size charts for fetal biometry measurements based on US fetal biometry for most common fetal parameters used including BPD, HC, FL, AC, and EFW in the Saudi population living in Dammam. Furthermore, this study investigates the blood pressure values during pregnancy and hematological changes during pregnancy and after delivery.

1.3 Problem statement

Many of the published charts show that the normal values of fetal biometry measurements are established fundamentally based on studies from Western or American populations (Jung et al., 2007) (as cited in Hegab et al., 2018). Such standards may be unsuitable for other populations; indeed, ethnic difference in fetal size and growth have been demonstrated in several studies (Hegab et al., 2018; Zhang et al., 2017; Peixoto et al., 2017; Parikh et al., 2014; Sletner et al., 2015; Araujo Junior et al., 2014; Babuta et al., 2013; Zaki et al., 2012; Leung et al., 2008; Jacquemyn et al., 2000). The ethnic factor is essential to consider in the fetal growth pattern, making it impossible for reference ranges of fetal biometric parameters from homogeneous populations to be applied in other populations, mainly heterogeneous populations (Peixoto et al., 2017). Parikh et al. (2014) observed that African-American fetuses have smaller AC values than Caucasian fetuses from 17^{th} to 23^{rd} weeks. They recommended that ethnicity-specific fetal growth curves be indicated to limit unnecessary follow-up.

Furthermore, Kwon et al. (2014) established reference charts for fetal biometric parameters in the Korean population and made a comparison with the UK and the North American populations. They showed that Korean fetuses had greater BPD, HC, and AC values in the first half of pregnancy but tended to measure progressively smaller with advancing GA. Compared to the Hong Kong population, Korean fetuses had a longer FL at any GA.

The published charts and curves recorded the variations of fetal biometry within a population of different ethnics in the same country and between high-altitude areas and sea-level areas. For example, a cross-sectional study conducted within the same country (Belgium) for different ethnicities of singleton fetuses, including 369 Belgian, 78 Moroccan, and 77 Turkish fetuses, showed no significant differences in BPD between the three different ethnic groups. Conversely, there was a significant difference for the HC, AC, FL, and EFW values calculated for both formulas (Shepard; Hadlock). They concluded that when evaluating the fetal size, care must be taken to use charts that are appropriate for the ethnic group studied. The use of customized charts of fetal size for pregnant of Turkish or Moroccan women origin should be deemed in such cases (Jacquemyn et al., 2000).

Raman et al. (1996) also showed that the growth rate of Indian fetuses is faster than that of Malay and Chinese fetuses in Malaysia. Additionally, they recommended that the FL parameter must be investigated independently in each population for better operational and functional decision-making in the area of obstetrics and gynecology. Honarvar et al. (1999) recommended that fetal anthropometric characteristics must be investigated independently in each population to enhance the efficacy of operational and functional decisions in the area of obstetrics and gynecology. Moreover, Honarvar et al. (2000) investigated the standard ultrasonic FL curve for an Iranian population; when comparing the results with a Western population, the study concluded that the results were unsuitable and inappropriate for other populations. Furthermore, Beigi and ZarrinKoub (2000) reported ethnic differences in the biometric measurements of different populations and emphasized the necessity of each population to accumulate their data and develop their nomograms.

In a study conducted in Aseer in southwestern Saudi Arabia (approximately 3200 m above the sea level), the anthropometric parameters of Saudi newborns in Abha (a high-altitude area) and Baish (a sea-level area) were investigated, which reflects intrauterine fetal life. These parameters (length, HC, and weight) were compared with those of the newborns of the United States. The study concluded that neonates from high-altitude areas are significantly lighter and shorter than those of the reference population and the neonates from a sea-level area of Saudi Arabia (Al-Shehri et al., 2005).

Recently, Knitza et al. (2018) established new fetal charts in Switzerland and compared them within the country with the previous reference charts of Kurmanavicius et al. (1999) to investigate whether fetuses are getting larger. They applied the same methodology as previously published. The chart comparison showed a minimal but clinically relevant increase in mean fetal body measures (BPD, HC, FL and AC). These data suggest that fetuses are growing larger within one generation; therefore, regular updates of fetal reference charts are necessary.

There are no existing data on fetal biometry size in Saudi Arabian society to identify the differences from other populations or to update over time. The typical US equipment used in Saudi health facilities has no inputs that consider the ethnicity variations in the measured fetal parameters. The absence of these data, which show the variations of fetal biometry with maternal ethnicity in the community, poses potential dangers not only to the fetuses but also to the pregnant mothers as a consequence of misinterpretation and wrong decisions.

In the Saudi context, there is only one published study on fetal BPD measurements that recruited only Saudi citizens from Riyadh (the capital city of Saudi Arabia). This study was performed by Al-Meshari et al. (1987), who assessed the normal BPD growth curves and reported bias in their results because of the extensive prevalence of consanguinity in their patients belonging to the Najdi tribes living around Riyadh. The study reported slightly skewed and leptokurtic distributions. The standard deviation (SD) in the results did not show a systematic increase with advancements in GA but had almost the same value each week of pregnancy. Hence, they recommended conducting the same study in other parts of Saudi Arabia. The correct methodology adopted by Altman and Chitty (1994) recommended that when constructing a new size chart, there is a need to consider the increasing variability of measurements as well as the increasing GA that was not achieved in the Al-Meshari study.

In the same context, Nasrat and Bondagji (2005) conducted a study in Jeddah (the second largest city in Saudi Arabia) that included only Arabic pregnant women with a specific GA (18^{th}, 28^{th}, and 38^{th} weeks), however, they did not focus on only Saudi fetuses in their study. They also compared their findings with Western studies, such as those by Hadlock et al. (1982a, 1982c, 1982d), Hadlock, Harrist, Deter, et al. (1982), Chitty et al. (1994a, 1994b, 1994c), and Krumanavicius et al. (1999a, 1999b). Furthermore, Nasrat and Bondagji (2005) emphasized the presence of significant variations in fetal measurements, especially in the later weeks of GA and at the extreme ranges of the fetal size. Nasrat reported that the presently used charts rely on data from Western populations may not be suitable for application on Arab fetuses; therefore, the adoption of locally developed parameters is recommended (Nasrat and Bondagji, 2005, p. 177).

Currently, the expected ranges of fetal weight and size throughout pregnancy have not been adequately determined in Saudi Arabia. Based on the researcher's knowledge, this is the first study performed to establish EFW charts in a Saudi setting. Moreover, no Saudi fetal charts have been published in the open literature for common fetal measurements (BPD, HC, FL, and AC). Additionally, Dammam city is a new area of Saudi Arabia to be investigated. Figure 1.1 shows a map of Saudi Arabia with its main cities. The distances between Dammam and Al-Riyadh, Al-Riyadh and

Jeddah, and Dammam and Jeddah are 403.5, 966.0, and 1369.5 km, respectively. Therefore, this study was conducted to explore fetal growth charts and equations for the most common fetal biometric parameters for normal Saudi pregnant women with specific menstrual dates. These women were evaluated from early weeks of GA until 41th weeks of pregnancy in Dammam city. The EFW was calculated from the HC, BPD, AC, and FL according to the Hadlock formula (1985).

Furthermore, a comparison with reliable and established fetal biometric charts from around the world was performed, including charts constructed by Chitty et al. (1994a, 1994b, 1994c), Hadlock et al. (1992, 1984, 1982a, 1982c, 1982d), Hadlock, Harrist, Deter, et al. (1982), Hadlock et al. (1991), and Krumanavicius et al. (1999a, 1999b), and from recently published studies of Western and Asian populations.

Distances between Dammam and Al-Riyadh = 403.5 km, Al-Riyadh and Jeddah = 966.0 km, Dammam and Jeddah = 1,369.5 km

Figure 1. 1: A map of Saudi Arabia with its main cities.

Furthermore, hematological changes during pregnancy have been reported. Apparently, the total blood volume in pregnant women increases from approximately 5 L before pregnancy to around 7–8 L at term (Regan, 2005). After delivery, women lose some blood when the placenta detaches from the uterus; however, because the amount of blood in the body increases by almost 50% during pregnancy, the body is well equipped to deal with this expected blood loss (Ueland, 1976). Compared with women who give birth vaginally, those who undergo cesarean sections lose more blood. Taylor (1979) reported the occurrence of substantial changes in hematological parameters during pregnancy and that the total blood volume during puerperium increases by approximately 1.5 L primarily to cater the needs of the new vascular bed. Because pregnancy puts extreme stress on the hematological system, elucidating the physiological changes is obligatory to interpret any need for therapeutic intervention (William and Cindy, 2005). The main hematological changes that occur during pregnancy are the changes in cell counts, hemoglobin levels, hematocrit, white blood cell/leukocytes counts, thrombocyte (PLT) counts, and red blood cell indices (Lewis et al., 2001).

One study reported a significant decline in PLT counts in pregnant women throughout pregnancy compared with the counts of non-pregnant women (Matthews et al., 1990). However, the counts were found to be within the normal range in most women with uncomplicated pregnancies (Verdy et al., 1997). Furthermore, various types of anemia can develop during pregnancy, but iron deficiency is the leading cause of anemia in pregnancy (Odekunle, 2010).

1.4 Study Objectives

This study was aimed at achieving the following objectives:

1- To determine the associations between the selected fetal biometry measurements (CRL, BPD, HC, OFD, AC, FL, and EFW) and gestational age.

2- To explore new size charts for CRL, BPD, HC, OFD, AC, FL, and EFW women from 6^{th} to 13^{th} week for CRL, and from 12 weeks for BPD, 20 weeks for HC and EFW, 13 weeks for FL, 17 weeks for OFD,15 weeks for AC to 41^{st} week of GA in Dammam, Saudi Arabia.

3- To compare the findings of the five selected fetal biometry measurements of Saudi singleton fetuses for normal pregnant women in Dammam with those of the USA, Europe, and Asia.

4- To explore the extreme ranges and equations for ANC parameters [systolic blood pressure (BP), diastolic BP, mean arterial pressure (MAP)] for normal pregnant women in Dammam, Saudi Arabia.

5- To determine the maternal or fetal factor, such as age, blood loss, gravida, baby's weight, and gender can have affected the BP and fetal biometry parameters in a normal pregnancy.

6- To determine the hematological changes of complete blood count of normal pregnant women in Dammam, Saudi Arabia.

1.5 Research Questions

The following research questions guided this study:

1. What are the mean values of fetal biometric parameters (BPD, HC, AC, FL, and EFW) at the gestational age ranging from 6^{th} to 13^{th} week for CRL, and from 12 weeks for BPD, 20 weeks for HC and EFW, 13 weeks for FL, 17

weeks for OFD, 15 weeks for AC to 41st week of GA in Dammam, Saudi Arabia?

2. Is there an association between the five fetal biometric parameters and gestational age?
3. What is the Saudi fetal size chart for each fetal biometric parameter (BPD, HC, AC, FL, and EFW) at gestational age ranging from 6th to 13th week for CRL, and from 12 weeks for BPD, 20 weeks for HC and EFW, 13 weeks for FL, 17 weeks for OFD,15 weeks for AC to 41st week of GA in Dammam, Saudi Arabia?
4. Do the Saudi fetal biometric parameters for gestational age ranging from 6th to 13th week for CRL, and from 12 weeks for BPD, 20 weeks for HC and EFW, 13 weeks for FL, 17 weeks for OFD,15 weeks for AC to 41st week of GA differ from those of other countries?
5. What are the associations between the blood pressure parameters and gestational age?
6. Is there any maternal or fetal factor, such as age, blood loss, gravida, baby's weight, and gender can have affected the BP and fetal biometry parameters in a normal pregnancy?
7. What are the hematological changes of complete blood count of normal pregnant women in Dammam, Saudi Arabia?

1.6 Study Significance

This study is significant in terms of its theoretical and practical contribution to the existing body of research knowledge. With regards to the theoretical contribution, the statistical analyses of the fetal measurements used in this study are expected to provide a better understanding on the fetal size of normal pregnant women, specifically in Dammam city, and create a database for fetuses in this environment, which may be useful in clinical anthropological practice. Clinical anthropology can be perceived as an applied branch of medical anthropology that has a direct association with the clinical situation for the diagnosis and treatment of patients. Furthermore, in the present study, the methodology, percentile tables, and charts will serve as a good reference source and database for future studies in this field of research. Moreover, this study sought to fill a gap in the related literature by exploring fetal size charts for normal pregnant women including the most popular fetal parameters such as BPD, HC, AC, FL, and EFW from the 14^{th} to 40^{th} weeks of gestation, particularly in Dammam city. Previous studies did not include all parameters with the correct methodology (Al-Meshari et al., 1987) and did not estimate the values throughout the pregnancy period (Nasrat and Bondagji, 2005).

Moreover, the findings of this study might contribute practically to obstetricians, embryologists, perinatologists, forensic pathologists, clinical anthropologists, and scientific investigators. As therapeutic methods are developed, these standards might be necessary for assessing the response to treatment because such standards will focus on the population from which the sample studied was drawn and therefore to which the results can be referred. Moreover, this will help eliminate the potential dangers posed by misinterpretation of findings that have not taken normal ethnic variations into account. Therefore, these findings will help reduce the misdiagnosis of fetal conditions. Furthermore, this study was performed to help sonographers make positive impressions on fetal assessment and dating. The findings of this work will help obstetrician-gynecologists make informed and reliable decisions in fetal and maternal management during antepartum, peripartum, and postpartum care. It will also impart professional competence and confidence in obstetric sonographers in their biometric findings and thereby reduce the tendency to skew findings to conform to the preset values in the equipment.

The main strength of this study lies in strictly following the instructions asserted by Altman and Chitty (1994), which is the accurate method recommended for this type of research; moreover, they clarify the most appropriate inclusion criteria to minimize the environmental constraints on fetal growth (Papageorghiou, Ohuma, Altman, et al., 2014; Papageorghiou, Kennedy, Salomon, et al., 2014). This study is further strengthened because the measurements were made according to standardized protocols by an experienced medical sonologist, assuring high-quality measurements and reducing "noise" owing to interobserver variation. Additionally, one US machine was utilized to reduce the error of using multiple machines. All the participants in the current study had their pregnancies dated by first trimester ultrasonographic fetal CRL measurement to confirm LMP dates.

1.7 Study Scope

This study focused on pregnant Saudi women lived in eastern province especially in Dammam and Alkobar cities. The eastern province is a major administrative center for the Saudi oil industry and has a strategic location nearby all Arabic Gulf countries (Qatar, United Arab Emirates (UAE), Bahrain, and Kuwait). It also includes the largest petroleum companies: Aramco (Arabian American Oil Company) and Sabic (Saudi Arabia Basic Industries Corporation, the Petrochemical manufacturing company). Accordingly, Dammam city is considered the best destination for most Saudi citizens from all over the country who are looking for a better life and job opportunities. The women who attended ANC and delivered their babies at the Departments of Obstetrics and Gynecology in King Fahd University Hospital and Maternity and Children Hospital. Of note, non-Saudi pregnant women who delivered in these hospitals were excluded from the study. In addition, cases of fetal abortions, stillbirth, and other abnormalities that occurred during or after delivery were excluded from the analysis. As this is a retrospective study, cases with abnormal fetal findings found in the pregnancy reports were excluded from the analysis. Finally, women with adverse health during gestation, such as those with diabetes and hypertension, were also excluded from this study.

1.8 Study Outline

This thesis comprises eight chapters. Chapter One presents the introduction and objectives, problem statement, and scope of this study. Chapter Two discusses the information regarding the prenatal and postnatal records. Chapter Three discusses the correlation between physics and biometric with the details of the parameters investigated in this study and presents the related literature reviews of the research. Chapter Four elucidates the research methodology focusing on data collection and using Statistical Package for Social Science (SPSS) software version 22 for analyzing the data. Chapters Five, Six, and Seven present the results of this study, including the ANC record, US biometry result, and blood analysis result, respectively. Finally, Chapter Eight concludes the research and lists some recommendations for further research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter describes the literature reviewed on the methods by which fetal size and age are assessed. The benefits of US-based fetal biometry are described. The review was also extended to the most commonly and less frequently used parameters in US studies. The influence of maternal and fetal characteristics and maternal ethnicity on fetal biometry have been reviewed. This chapter also defines both prenatal and postnatal findings obtained during pregnancy. In addition, the concept of the complete blood count (CBC) test is discussed which is essential to assess the well-being of both the mother and the fetus.

2.2 Trimesters of Pregnancy

Every pregnancy comprises three stages of trimesters as follows: (a) the first trimester (≤13th weeks of GA), (b) the second trimester (14th to 26th weeks of GA), and (c) the third trimester (≥27th weeks of GA). All these stages are based on the developmental age of the fetus. In general, the expected gestation length is 40 ± 2 weeks. Thus, the EDD is the date 40 weeks after the first day of the LMP; however, if the LMP date is uncertain, an early US scan (CRL)] can help calculate the fetal age to determine the EDD (Regan, 2005).

In the first trimester, the embryo attaches to a small yolk sac that offers nourishment. Some weeks later, the placenta begins to form and controls all nutrient transfer to the embryo. During this time, the embryo is surrounded by the fluid inside the amniotic sac (Regan, 2005). By 7 weeks, the embryo is approximately 10 mm long from the head to the bottom (known as the CRL). After 12 weeks from the LMP date, all organs, muscles, limbs, and bones are completely formed and in place in the fetus; hereinafter, the fetus just grows and matures (Regan, 2005).

In the second trimester, the fetus weighs approximately 25 g, and the hearing ability of the fetus commences around this time. With time, the body grows and the fetal head and body are more in proportion. In this trimester the BPD, i.e., the diameter between the two sides of the head, can be measured ultrasonographically. Likewise, the HC, i.e., the circumference of the fetal head, and the FL, i.e., the length of the longest bone in the body that reflects the longitudinal growth of the fetus, are evaluated in this trimester (Regan, 2005).

In the third trimester, the fetus is highly active, and the mother is probably aware of several movements. Despite the rapid development of the lungs, the fetus would not be able to completely breathe on its own until approximately 36 weeks. At this stage, the fetal head is positioned downward (also known as the cephalic presentation) with the anticipation of delivery. Furthermore, the fetal brain and nervous system are completely developed, and bones, except for the skull bones, are hardening at this stage. The skull bones remain soft and detached up to the delivery time to facilitate the delivery process through the birth canal. Reportedly, the gentle bone movement ensures a safe and healthy delivery by protecting the head and the brain (Regan, 2005). Notably, evaluating the AC ultrasonographically is a critical diagnostic requirement in the late stage of the third trimester. The AC evaluation reveals the fetal weight and size more than it predicts the age. The estimated fetal weight evaluation in this trimester reveals the fetal weight using polynomial equations comprising measurements, such as the BPD, FL, and AC (Regan, 2005).

2.3 Assessment of Fetus Size and Age

Different methods are used to evaluate the size or GA of the fetus. These may be either direct measurements of fetal anatomy or indirect measurements through reliance on menstrual records. Direct evaluation is based on US measurements of several parts of the fetal anatomy; this is referred to as fetal biometry (Ghani et al., 2014; Degani, 2001). Indirect evaluation includes clinical palpation, fundal height measurement, and the LMP of the pregnant woman.

2.3.1 Symphysis–Fundal Height

The symphysis-fundal height (SFH) is a measurement of the pregnant abdomen, using a tape, from the highest point of the uterus (fundus) to the symphysis pubis. It is simple, convenient, safe, inexpensive, and widely used during ANC to measure the size of the uterus, fetal growth, and development (Pay et al., 2015).

2.3.2 Last Menstrual Period

The LMP is a maternal parameter based on the menstrual history of the pregnant woman. GA can be calculated from the LMP, which is based on Naegele's theory stating that the average human pregnancy is 266 days from conception or 280 days (40 weeks) from the beginning of the LMP. In order to calculate GA, one should start with the first day of the last period (the LMP), by adding seven days, and subtracting three months (or adding nine months), and adding one year. For example, if the first day of the LMP was July 1, 2016, counting forward nine months brings us to April 1, 2017. Adding seven days provides us a due date of April 8, 2017.

Campbell et al. (1985) reported that 45% of pregnant are unsure of their menstrual dates because of irregular cycles, oral contraceptive use within two months of conception, bleeding during early pregnancy, or poor recall. Savitz et al. (2002) re-echoed this assertion by stating that in approximately 40% of pregnancies, the LMP is either unknown or not reliable. The only truly confirmed clinical history is one in which the dates of ovulation, fertilization, and implantation are accurately known, such as in assisted reproductive technology (ART), in which records include the date of oocyte retrieval, and other methods of timed ovulation and fertilization (Butt et al., 2014).

Thus, in some cultures, particularly where literacy levels are low, the LMP can be very unreliable (White et al., 2012; Rijken, 2009). Hence, Nakling et al. (2005) categorically stated that US assessment of GA up to 24 weeks provides the most accurate assessment of the fetus and the most accurate prediction of the EDD and is more reliable than the LMP.

2.3.3 Ultrasound Fetal Biometry

The usefulness of US imaging in modern obstetric care and specifically fetal biometry cannot be overemphasized. The prenatal assessment of GA and fetal growth using ultrasonography has achieved a pre-eminent role in prenatal care in both developing and developed countries (Keikhaie et al., 2017; Merialdi et al., 2005). This imaging technique facilitates evaluation of fetuses for anomalies, assuring fetal health, and evaluation of fetal development and growth. When implemented with quality and precision, US alone is more accurate than a certain menstrual date for identifying GA in the first and second trimesters (≤23 weeks) in spontaneous conceptions. Butt et al. (2014) stated that the US method is the best methodology for determining the delivery date.

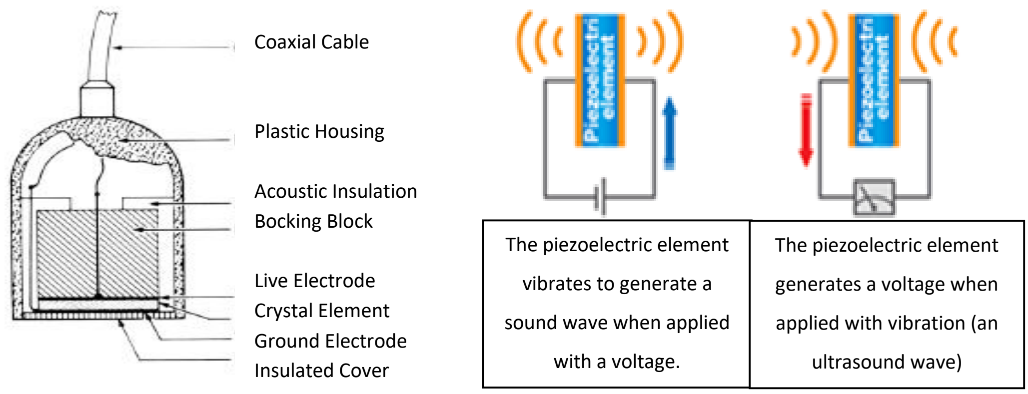
2.4 Utilized Ultrasound in Prenatal Fetal Assessment

US fetal biometry is an essential technology in education and research. With the help of this technology, every part of the fetal anatomy can be imaged. Measurements of the fetal head, spine, abdomen, long bones, cardiac function, and fetal vascular caliber can be obtained. The most commonly used measurements for biometry are those of the head, abdomen, and femur. These biometric measurements can be utilized to estimate GA and EFW, assess interval fetal growth, and determine fetuses who are either growth restricted or macrosomic. Biometry is, hence, a critical element of obstetrical practices. These measurements may effect intrapartum and antepartum management and may be utilized to predict the outcomes of peripartum (Zaliunas et al., 2017).

2.4.1 Physics in Ultrasound

Ultrasonography is a sophisticated radiological method for locating, evaluating, and delineating buried structures by assessing the reflection of high-frequency (ultrasonic) waves; US is a sound wave with frequencies higher than those audible to humans (>20,000 Hz). US images (sonograms) are generated by sending US pulses into tissue using a probe called ultrasonic transducers (Figure 3.1a). Typically, the sound waves are mechanical disturbances that are created by a crystal in a handheld transducer using the conversion of electrical energy into sound energy utilizing the pulse-echo technique; as this sound wave goes through the body, it reflects back from various tissue surfaces and is turned into electrical energy. Although transducers for flaw detection are available in a wide variety of sizes, frequencies, and case styles, most have a typical internal structure (Enriquez & Wu, 2014).

The application of a short pulse of electricity to a piezoelectric crystal creates US waves; this alters the width of the crystals, causing particles of the adjacent medium to vibrate. These vibrations propagate via the medium as a pulsed sinusoidal wave. The US-based diagnosis is obtained by interpreting echoes produced by reflection or scattering of US at tissue interfaces or from scattering from heterogeneous structures within the tissue (Enriquez & Wu, 2014). A computer shows both the position and power of each echo as an image on a screen. Calculations of the distance to the sound-reflecting surface in addition to the known orientation of the sound beam produces a two- or three-dimensional image. Piezoelectric crystals are situated at the footprint of the probe and are arranged in line with the shape of the probe tip. The footprint is a transmitter and receiver of the US beam during scanning. Most current probes utilize synthetic plumbum zirconium titanate rather than the quartz crystals that were utilized in earlier units. These plumbum zirconium titanate crystals are necessary for the image quality acquired amid the scan and can be misaligned or harmed when probes are dropped, crushed, or on impact with other objects (Enriquez & Wu, 2014). Figure 2.1 shows the part of transducer probe and the function of the piezoelectric crystal element (NDK, 2016).



a) The part of transducer probe.

b) The function of crystal element.

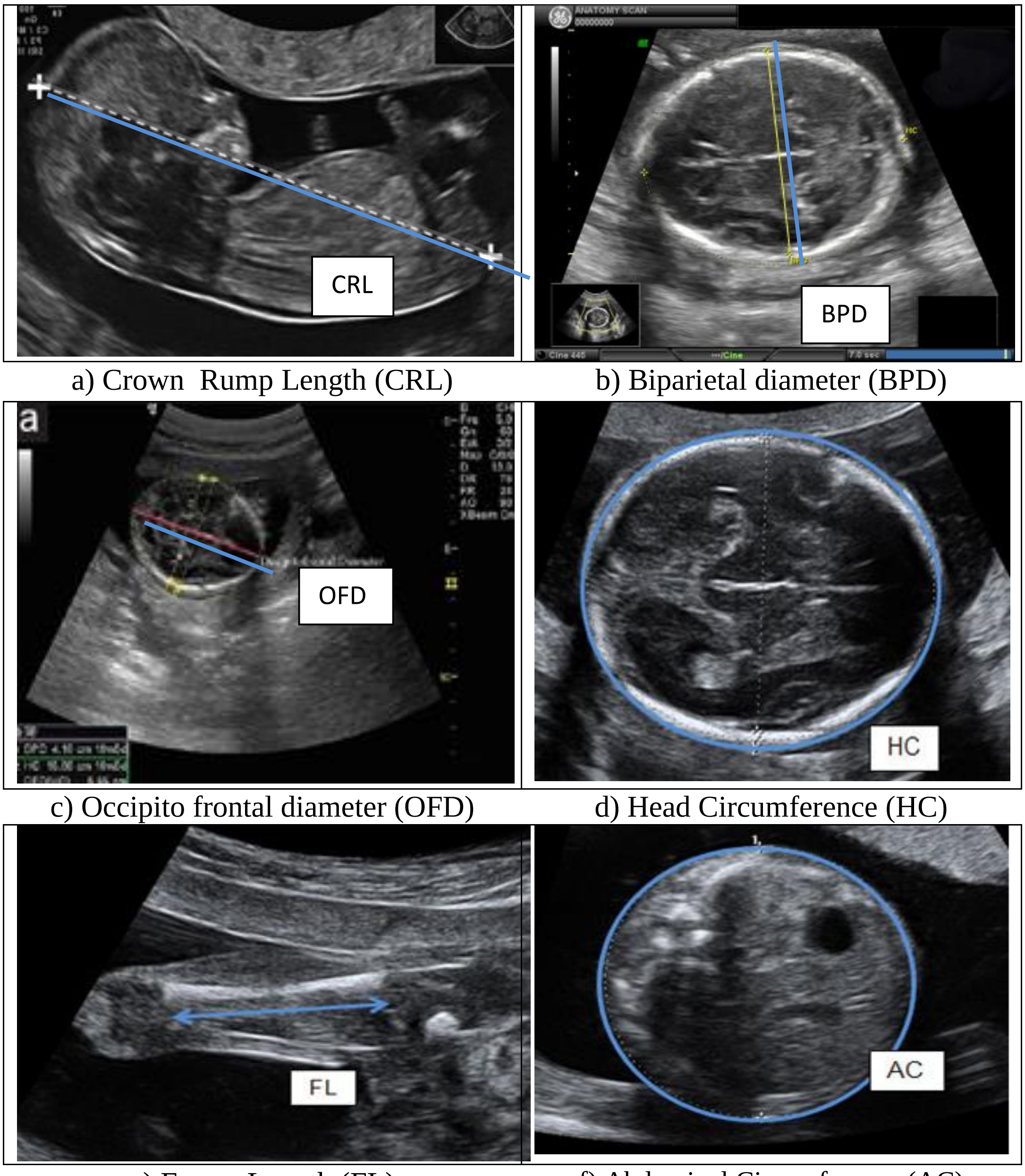
Figure 2.1: The part of transducer probe (NDK, 2016).

2.4.2 Safety of Ultrasound

Evidently, obstetric ultrasonography is a low-risk examination. Over the years, several studies on the effects of US on the functional and morphological states of biological cells with the aim of identifying adverse effects of US on the mother or the fetus have failed to determine any significant problem (Rasmussen et al., 2010; Ho et al., 2009; Tu et al., 2004). In addition, the non-invasive and non-ionizing nature of US and its cost-effectiveness account for its wide prevalence in clinical practice and validate its safety when used in the right medical situation when performed by trained and accredited clinicians (Smith & Smith, 2002).

2.5 Frequently Used Parameters in Ultrasound Fetal Biometry Studies

US fetal biometry involves the use of high-frequency sound wave imaging technology to scan the fetus with the aim of assessing its general health; US fetal biometry includes measurements of the various segments of the fetal anatomy (Zaliunas et al., 2017). Every part of the fetal anatomy can be imaged: the fetal head, spine, heart and major vessels, abdomen, and long bones. These biometric measurements can be used to estimate GA and EFW, identify fetuses who are either growth restricted or have macrosomia, and assess fetal growth. The most common parameters are described below and illustrated in Figure 2.2, such as: the CRL measurement which measured from the length of human embryos from the top of the head (crown) to the bottom of the buttocks (rump) (Salomon et al., 2014).



a) Crown Rump Length (CRL) b) Biparietal diameter (BPD)

c) Occipito frontal diameter (OFD) d) Head Circumference (HC)

e) Femur Length (FL) f) Abdominal Circumference (AC)

Figure 2.2: An ultrasound fetal biometry image (Smith & Smith, 2002).