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Using computer expert system to solve complications primarily due to low and excessive birth weights at delivery: Strategies to reviving the ageing and diminishing population

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Abstract

The world now lives in an ageing society. Significant empirical evidence from the literature revealed that the world's total fertility rate (TFR) estimate has experienced a declining trend from 5.30 in 1963 to 2.3 in 2020. The TFR for 2023 for the United States was 1.84, Canada 1.57, United Kingdom 1.63, Germany 1.58, Japan 1.39, China 1.45, Nigeria 4.57, India 2.07, Ghana 3.61, with Taiwan 1.09 and Niger 6.73 having the least and highest respectively. Non-adherence to God's childbearing principles, a female's age when she has her first child, educational opportunities, access to family planning, and government acts and policies affecting childbearing are all factors that may influence TFR. Despite the danger posed by the declining TFR trend, childbearing challenges and complications primarily due to low and excessive birth weights at delivery have heightened this danger. This study highlights strategies to leverage the provision of a computerized expert system (ES) solution to the problems of complications primarily due to low and excessive birth weights at delivery. A Knowledge-Based System (KBS) framework to simulate the problem-solving behavior of an expert in a narrow domain or discipline to unite the accumulated expertise of individual disciplines such as gynecology, ultrasonography, computer software design, and engineering was adopted. Fetal weight has been found to be a function of fetal head circumference (HC), femur length (FL), abdominal circumference (AC), and biparietal diameter (BPD) and predictable with a polynomial equation. Also, fetal age has been found to be a function of fetal weight and predictable by an equation. The equations for the determination of conception date and delivery dates were derived. The Expert System (ES) primarily estimates fetal parameters (fetal weight, fetal age or gestational age, conception date, and delivery date) in the first trimester using ultrasonographic fetal biometric data. The result of this study may eliminate or reduce the occurrence of potential complications associated with the birth of both small and excessively large fetuses, thereby contributing to reviving the world declining population.

Keywords: Expert System; TFR; KBS; Ultrasonography; Ageing world; Birth Weights at Delivery

1. Introduction

A woman wants to know if she is pregnant even before she sees her menses. She also wants to know how far along the pregnancy is and, as a result, when she can expect to give birth. Determining gestational age is critical for planning appropriate fetal care and reducing or preventing low fertility in women. It provides important information regarding expected or potential problems and directly impacts the medical treatment plan for the baby. Traditionally, the due date was based on the following: - the last menstrual period; - an early pelvic examination; - uterine size measurement; - feeling or quickening the baby's first movements. All of the above are still part of routine obstetrical care, but they are very unreliable for some groups of women, such as: --overweight or obese women; --those who are unsure of their last menstrual period; --women who have been taking oral contraceptives; --women who have irregular menstrual cycles [12]. Although an oral interview has a significant advantage as a method of clinical diagnosis because it allows the

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clinician to hear the details of the situations directly from the patient involved, the patient's account of the intensity of the situation may be insufficient because the patient may attempt to withhold some facts that he or she believes are not respectable or shameful, or even unnecessary to effect a reliable conclusion because they may be an evasive tactic. The prenatal complications associated with low birth weight are attributable to preterm delivery, intrauterine growth restriction (IVOR), or both. On the other hand, potential complications associated with excessively large fetuses' delivery include shoulder dystocia, brachial plexus injuries, bony injuries, and intrapartum asphyxia [14]. Maternal risks associated with the delivery of an excessively large fetus include birth canal and pelvic floor injuries, as well as postpartum hemorrhage. Newborn and maternal complications associated with birth weights greater than 4000 g have been linked to low fertility rates in women, among other things [14].

TFR has decreased globally, particularly in most developed and developing countries [40]. Total Fertility Rate (TFR) estimates the number of children that would be born to a woman if she were to live to the end of her reproductive years and bear children in agreement with age-specific fertility rates presently observed. The TFR, which includes only live births, is the most widely used fertility measure in program impact evaluations because it is unaffected by differences or changes in age-sex composition, provides an easily understandable measure of hypothetical completed fertility, and is a more direct measure of the level of fertility than the crude birth rate since it refers to births per woman [40]. According to [40], TFR is a more direct measure of the level of fertility than the crude birth rate since it refers to births per woman. TFR has experienced a declining trend from 5.30 in 1963 to 2.3 in 2020 [47]. The TFR for 2023 for the United States was 1.84, Canada 1.57, United Kingdom 1.63, Germany 1.58, Japan 1.39, China 1.45, Nigeria 4.57, India 2.07, Ghana 3.61, with Taiwan 1.09 and Niger 6.73 having the least and highest respectively [40]. Human growth, economic growth, cultural stability, and other factors appear to be fading [9], [15] and [17], and their positive effects are likely to be offset by the world's ageing population [48].

Aside from factors such as ergonomics and cultural influence [2], non adherence to God's childbearing principles, a female's age at her first child, educational opportunities, access to family planning, and government acts and policies that impact a declining population and fertility rate, childbearing challenges and complications primarily due to low and excessive birth weights at delivery also pose some dangers to the declining TFR trend. This study highlights strategies to leverage the provision of a computerized expert system (ES) solution to the problems of complications primarily due to low and excessive birth weights at delivery. A number of parameters for determining the conception and delivery dates have been derived using the fact that pregnancy typically lasts 40 weeks, or nine (9) months [13] and [30]. The Expert System (ES) primarily estimates fetal parameters (fetal weight, fetal age or gestational age, conception date, and delivery date) in the first trimester using ultrasonographic fetal biometric data. Relevant system analyses, including a literature review, were carried out in order to transform system objectives, analyses, and inputs into the required expert system solution. Fetal weight has been found to be a function of fetal head circumference (HC), femoral length (FL), abdominal circumference (AC), and biparietal diameter (BPD) and predictable with a polynomial equation [2], [20], [33], and [34]. Also, fetal age has been found to be a function of fetal weight and predictable with an equation [25], [33], and [34]. A Knowledge-Based System (KBS) framework to simulate the problem-solving behavior of an expert in a narrow domain or discipline to unite the accumulated expertise of individual disciplines such as gynecology, ultrasonography, computer software design, and engineering was adopted.

The purpose of this study is to implement sustainable ES primarily for the accurate estimation of fetal parameters (fetal weight, fetal age or gestational age, conception date, and delivery date) in the first trimester using ultrasonographic fetal biometric data to solve or reduce the problems of complications primarily due to low and excessive birth weights at delivery. The findings from this study may eliminate or reduce the occurrence of potential complications associated with the birth of both small and excessively large fetuses, thereby contributing to the revitalization of an aging and shrinking population.

1.1. Problem Statement

The declining population and fertility rate are on an alarming rise. Human growth, economic growth, cultural stability, and other positive effects appear to be fading [9], [15] and [17], and their benefits are likely to be offset by the world's ageing and fading population [48].The general IT problem postulated in this study was poor systematic approach in eliminating or reducing the occurrence of potential complications associated with the birth of both small and excessively large fetuses. The specific IT problem is that some ES design specialists across the board lack strategies to accurately estimation of fetal parameters (fetal weight, fetal age or gestational age, conception date, and delivery date) in the first trimester using ultrasonographic fetal biometric data required to solve or reduce the problems of complications primarily due to low and excessive birth weights at delivery.

1.2. Research Question

What are the appropriate and sustainable ES for accurate estimation of fetal parameters (fetal weight, fetal age or gestational age, conception date, and delivery date) in the first trimester using ultrasonographic fetal biometric data to solve or reduce the problems of complications primarily due to low and excessive birth weights at delivery?

1.3. Literature Review

Most medical expert systems address very specific problems that are typically procedural, methodological, and tutorial intensive. Recently, these expert systems have adopted the effective use of computers and human resources. Today, both cultural and procedural changes are needed to support the medical profession of the future, and these changes will require expert software systems involving object-relational database systems and deductive databases (rules and facts). In this article, the needs for the design, implementation, and application of computer software that can mimic human thought, understand logic, and handle a range of problems that are coextensive with the range of problems to which a human mind has been applied to the topic discussed are examined, with the objective of solving the problems of complications primarily due to both low-birth weight and excessive fetal weight at delivery, which are usually associated with an increased risk of newborn complications during labor and the prepartum. According to [14], birth weight and gestational age are both important determinants of postpartum outcome, while relative and attributable risks are significantly higher for fetuses weighing more than 4000 grams at delivery compared to controls weighing less than 4000 grams ($p < 0.01$ in all cases and $p < 0.05$ for birth canal/perineal lacerations). As a result, any design that provides an accurate and effective estimation of the same is greatly appreciated. This is the purpose of this study. Some researchers have claimed that, for cases of macrosomic fetuses, attempts to predict birth weight from fetal measurements obtained via ultrasonography have proved difficult from the standpoint of improving clinical outcomes [19], [37], [39], and [49]. Some studies claim that ultrasonographic fetal biometric assessments are no more predictive of fetal macrosomia than clinical assessments of fetal size by simple external abdominal palpation [6]. They claimed that the method of ultrasonographic fetal biometry is both complicated and labor-intensive, potentially limited by suboptimal visualization of fetal structures, and that it also requires costly sonographic equipment and specially trained personnel. These issues, however, will be greatly reduced with computerized ultrasonographic fetal predictions. By contrast, clinical palpation is a subjective methodology that must be employed at or near the date of delivery, and it is both patient- and clinician-dependent for its success (i.e., less accurate for obese than nonobese gravidas, significant for inter-observer variation in birth weight predictions even among experienced clinicians) [32]. Ultrasonographic fetal biometry predictions are inevitable [12].

1.3.1. Expert System Solution to Complications Primarily Due to Low and Excessive Birth Weights at Delivery

Combining the different methods of fetal weight prediction to improve their overall accuracy may be possible. By combining the independent information about fetal size obtained from the three different approaches (i.e., clinical examination, quantitative assessment of maternal characteristics, and ultrasonographic fetal biometry), the predictive value of fetal weight estimations can be dramatically improved [46]. Undergoing an ultrasound procedure early in the first trimester (weeks 1–12) allows a more accurate due date [12]. The mean birth weight has been described as a function of gestational age [1]. Some studies subdivide such results into those that apply to women of different races: male versus female fetuses and primiparous versus multiparous gravidas. Standard fetal growth curves are useful for estimating the range of expected fetal weight at any particular gestational age. Without adequate gestational dating, the standard fetal growth curves cannot be interpreted successfully [3]. Therefore, this paper provides computerized clinical and private solutions to these problems associated with accuracy, effectiveness, and efficiency. With the advent of 3-dimensional fetal imaging, optimism that these new technologies can provide even better fetal weight estimations may be justified, but the advantages of estimating fetal weight using these newer techniques have not yet been demonstrated. There is, therefore, an existing problem of empirically and accurately estimating these fetal parameters. This can be achieved with an expert system, which is seen to unite the accumulated expertise of individual disciplines such as gynecology, ultrasonography, computer software design, and engineering into a framework that best addresses the specific, on-site needs of clinicians required for accurate and empirical estimation of fetal parameters.

An Expert System (ES), also called a Knowledge Based System (KBS), and other system automation have become critically important in the simulation of the problem solving behavior of a human expert in a narrow domain or discipline [29]. It consists of a knowledge base (facts), production or inference rules ("if.., then.."), and an inference engine (which controls how "if.., then.." rules are applied to facts) [23]. In this study, expert systems will be seen to unite the accumulated expertise of individual disciplines, such as gynecology, ultrasonography, and computer software design and engineering, into a framework that best addresses the specific, on-site needs of patients. It shall combine experimental and experiential knowledge with the intuitive reasoning skills of a multitude of specialists to aid doctors, patients, parents, and homes in making the best decisions [41]. [41], however, identified the most important modules that make up a rule-based expert system in what they called the "expert system shell," shown in Figure 1 below. These include user interfaces, which may use menus, natural language, or any other style of interaction. Then an inference engine was used to reason with both the expert knowledge (extracted from our friendly expert) and data specific to the particular problem being solved.

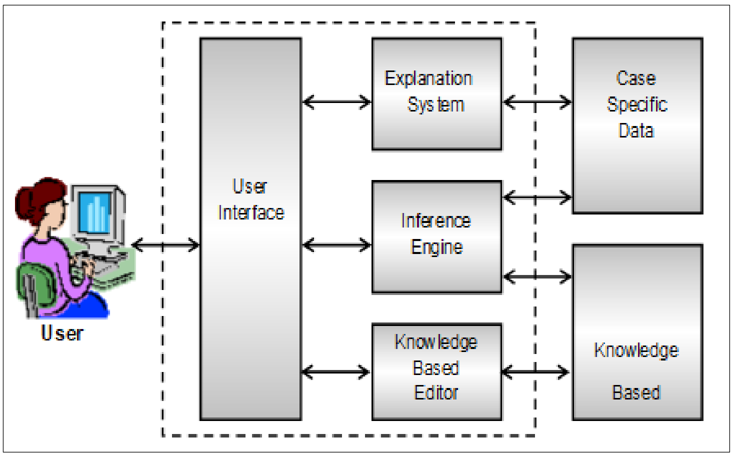

Figure 1 Expert System Shell

The user interface may use menus, natural language, or any other style of interaction, while an inference engine is used to reason with both the expert knowledge (extracted from our friendly expert) and data specific to the particular problem being solved. The expert knowledge will typically be in the form of a set of IF THEN rules; the explanation subsystem, which allows the program to explain its reasoning to the user, The knowledge-based editor helps the expert or knowledge engineer easily update and check the knowledge base. The ES Shell codes are done with PROLOG (Programming in LOGic). Tools for system design include, among others, organizational structure, a data dictionary, a data flow diagram, a systems flow diagram, etc.

1.3.2. Data Flow Diagram of the System

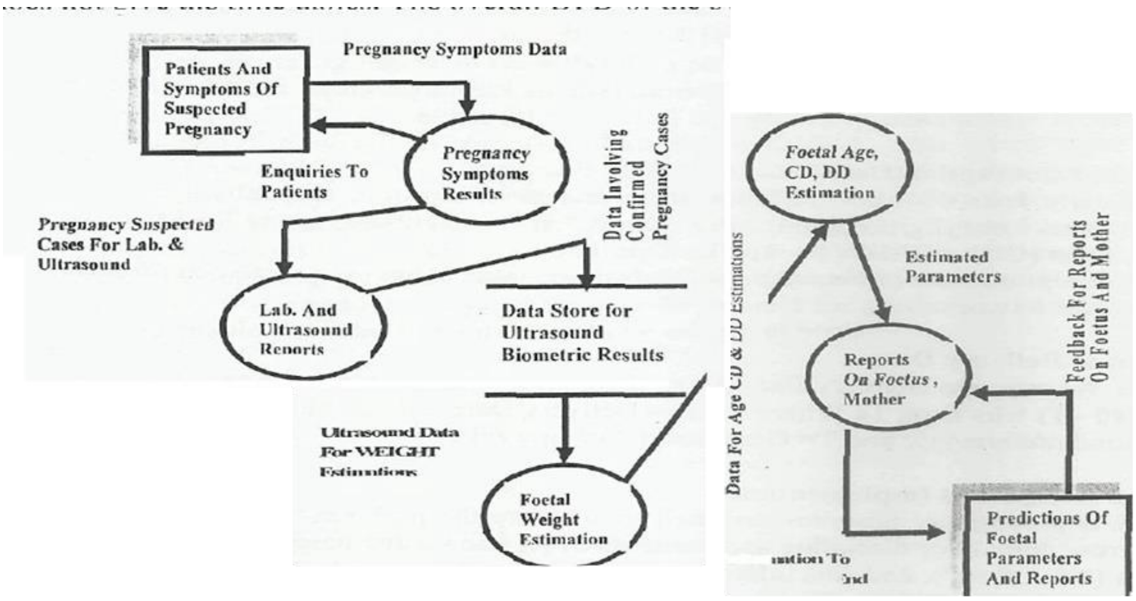

Figure 2 Data Flow Diagram of the System

The Data Flow Diagram (DFD) is a graphical representation of the "flow" of data through the information system that shows the flow of data or information, partitioned into single processes or functions, grouped together, or decomposed into multiple processes [10] and [45]. It illustrates how data are processed by a system in terms of inputs and outputs [24] and is used to visualize data processing [16]. It is like a railroad map that shows where the train is laid but does not give the time tables. The overall DFD of the system is shown in Figure 2.

2. Material and methods

This study incorporated the use of a narrative review approach that aligns with the consensus of many researchers on the narrative review research methodology approach. It also incorporated the application of empirical results from journals to ES to simulate the problem-solving behavior of a human expert in a narrow domain or discipline. The consensus of many researchers on narrative review research methodology is that it is best suited for comprehensive studies that aim at synthesizing a stream of research, identifying problems, gaps, and research opportunities within it, and providing a foundation for drawing holistic interpretations or conclusions and significant interpretations based on the existing theories, conceptual framework, and models within the review boundaries [8], [22], [36], and [42]. Data must be narrated [7] and [35], as data items do not speak for themselves. The narrative review approach involved the review, analysis, and integration of different, related, and interactive approaches and research findings [8] and [36], with the aim of exercising a holistic-content reading and drawing holistic interpretations or conclusions [5] and [28], based on the reviewers' own experiences and existing theories and models that may answer the research question. A narrative study approach is most appropriate for a descriptive or explanatory study that allows for a narrative-constructivist and integration approach [8], uses mainly narrative methods of data collection and analysis, and produces a final narrative report [27]. The narrative review methodology provides significant strengths that have the ability to establish platforms for the comprehension of diverse and numerous understandings derived from multiple data sources and research findings. It also allows the researchers to conduct reflective practices and acknowledge the views and knowledge of other researchers [11] and [31]. Through methodological triangulation, a coherent justification of data interpretation is maximized by providing a platform for engaging multiple sources of data to gain multiple perspectives and maximize the reliability and validity of data. Methodological triangulation helps to confirm the reliability and validity of the information collected and the justification of interpretations from the reviews.

2.1. Data Collection

Table 1 Ultrasonograohic Fetal Biometric Algorithms For Calculating Estimated Fetal Weight

SOURCE	YEAR	EQUATION
Shepard	1982	$Log_{10} BW^* = -1.7492 + 0.0166 (BPD^{\dagger}) + 0.0046 (AC^{\ddagger}) - 0.00002646 (AC X BPD)$ ... Eqn.. 1
Campbell	1975	$Ln^{\S} BW = -4.564 + 0.0282 (AC) - 0.0000331 (AC)^2$ ... Eqn.. 2
Hadlock 1	1985	$Log_{10} BW = 1.326 - 0.0000326 (AC X FL^{\|}) + 0.00107 (HC^{\P}) + 0.00438 (AC) + 0.0158 (FL)$ ... Eqn.. 3
Hadlock 2	1985`	$Log_{10} BW = 1.304 + 0.005281 (AC) + 0.01938 (FL) - 0.00004 (AC X FL)$ Eqn.4
Hadlock 3	1985	$Log_{10} BW = 1.335 - 0.000034 (AC X FL) + 0.00316 (BPD) + 0.00457 (AC) + 0.01623 (FL)$ ... Eqn.. 5
Warsof 1	1986	$Ln BW = 4.6914 + 0.00151 (FL)^2 - 0.0000119 (FL)^3$ ... Eqn.. 6
Warsof 2	1986	$Ln BW = 2.792 + 0.108 (FL) + 0.000036 (AC)^2 - 0.00027 (FL X AC)$ Eqn.. 7
Combs	1993	$BW = [0.00023718 X (AC)^2 X (FL)] + 0.00003312 (HC)^3$ ... Eqn.. 8
Ott	1986	$Log_{10} BW = 0.004355 (HC) + 0.005394 (AC) - 0.000008582 (HC X AC) + 1.2594 (FL/AC) - 2.0661$ Eqn.. 9
Schild,	2004	$BW = 5381.193 + 150.324 X HC + 2.069 X FL^3 + 0.0232 X AC^3 - 6235.478 X log(HC)$ ... Eqn.. 10
Merz	1988	$BW = -3200.40479 + 157.07186 AC (cm) + 15.90391 (BPD)^2 (cm)$. Eqn.. 11

Where

BPD - Fetal Biparietal Diameter (Mm)
Ln – Natural Logarithm
HC – Fetal Head Circumference (Mm)
BW - Estimated Fetal Weight (G)
AC - Fetal Abdominal Circumference
FL - Fetal Femur Length (Mm)

Some peer-reviewed research findings from journals and other articles that are relevant to our study objectives and consistent with our research question and conceptual framework were reviewed. Our key search words were tailored toward identifying the appropriate ES and KBS framework to simulate the problem-solving behavior of an expert in a narrow domain or discipline that unites the accumulated expertise of individual disciplines such as gynecology, ultrasonography, computer software design, and engineering approaches to meet the objective of this study. Two major sets of secondary data were also collected: *ultrasonographic fetal biometric algorithms for calculating estimated fetal weight (Table 1 above), and world TFR estimates from 1960 to 2020,* as shown in Tables 2 below.

Table 2 World TFR Estimate from 1960 to 2020 (1960 = 1)

Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
TFR Estimate	4.7	4.6	5.0	5.3	5.1	5.1	5.0	4.9	5.0	4.9	4.9	4.7	4.6	4.4	4.3	4.1
Code	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
TFR Estimate	4.0	3.9	3.8	3.8	3.7	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.3	3.3	3.1
Code	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**
TFR Estimate	3.0	3.0	2.9	2.9	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.6
Code	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**NA**	**NA**	**NA**
TFR Estimate	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4	2.4	2.3	NA	NA	NA

Source: Total Fertility Rate (Births per Woman). (Word Bank Data, 2020).
https://data.worldbank.org/indicator/SP.DYN.TFRT.IN?end=2020&start=1960&view=chart

3. Result and Discussions

The data in Table 1 above, titled "*Ultrasonographic Fetal Biometric Algorithms For Calculating Estimated Fetal Weight,*" were set up as functions of fetal head circumference (HC), femoral length (FL), abdominal circumference (AC), and biparietal diameter (BPD), and were predictable with a polynomial equation [43]. It was used in the determination of fetal parameters: gestational age, conception date, and delivery date. Gestation refers to the period of growth and development of a baby inside the mother's uterus between conception and the baby's birth. This period of gestational or fetal age is measured in weeks from the first day of the woman's last menstrual cycle to the current date and is measured in weeks. A gestation of normal gravity is roughly 40 weeks, with a normal range of 38 to 42 weeks. Various methods for determining gestational age exist. Whatever system of measurement is used, if a process is ineffective, surely the outcome or product will be inversely ineffective. As a result, the more accurate the process used in estimating fetal age, the better the results. One of the purposes of this study is to make available for medical doctors, clinicians, or patients a snappy and periodical estimation of fetal age without going through mathematical stress. Fetal weight has been set up as a function of fetal head circumference (HC), femoral length (FL), abdominal circumference (AC), and biparietal diameter (BPD), and is predictable with a polynomial equation [43]. Fetal age has also been set up as a function of fetal weight and is predictable with an equation. Table 1 compiles algorithms that use standard defined fetal measurements or a combination of AC, FL, and either BPD or HC to predict birth weight and are generally comparable in terms of overall accuracy. Equation 11 of Table 1 guarantees 71.4% reliability in predicting fetal weight with a mean absolute weight difference of 22 Ig for the complete study [26]. The validity of this formula, according to [26], could be defined as follows: - BPD 7.0-10.5 cm, AC 21.8-36.5 cm, with all measurements taken from the outer to the outer margin, were compared prospectively in a group of 87 fetuses with six currently available equations for estimating weight in the preterm fetus and using stepwise regression analysis with gestational age.

Nowadays, fetal biometric parameters are employed to yield the best-fit formula for predicting fetal weight at birth. The authors adopted this as an implementable formula for predicting fetal weight at birth. Therefore, fetal age (T) can be estimated from fetal weight (FW) with the equation **T = (3FW + 2.730) /0.091.** [38] Eqn. 12, where FW denotes fetal weight. As a result, using gestational age, the conception date can be calculated back from the date of kill of a pregnant female. Pregnancy typically lasts 40 weeks, or 9 months, and at conception, the unborn child is already considered two weeks old [18], [21], and [44]**.** As a result, if the gestational age is T weeks and measured on a given date DM, the date of conception (CD) can be calculated as **CD= DM - (T - 2) wks**, Eqn. 13. *CD = Conception Date* (DD/MM/yy);DM = date gestational age (dd/mm/yy) was determined; and *T: Gestational Age in Weeks*. As a result, if we know the gestational age, we can estimate the delivery date (DD) using the equation **DD = DM + (40 - T) wks** Equ. 14. *Where DD = Delivery Date* (dd/mm/yy); *DM = date gestational age (dd/mm/yy) was determined; andT = gestational age in weeks.*

From the data shown in Table 2 above, captioned "*World TFR Estimate from 1960 to 2020 (1960 = 1)".* linear regression analysis was conducted using Statistical Package for Social Sciences (SPSS) version 21. The result is shown in Figure 3 below. The results show that with 99% confidence, world TFR is statistically predictable with the linear equation **TFR**

= - 0.050 X + 4.999 (R^2 = 0.917, p <0.01, F = 336.673, p <0.01), where X = code assigned to year 1960 = 1. The test is therefore highly statistically significant. An **R^2 of 0.917** statistically implies that about 91.7% of the variations in TFR are affected by the variations in years. Making predictions with the equation **TFR = -0.050 X + 4.999** for the years 2030, 2040, and 2050, the world's total fertility rate (TFR) estimate will be given as 1.4, 0.9, and 0.4, respectively, if nothing positive is done. This declining trend in the Total Fertility Rate (TFR) estimate could drive the world population to extinction by 2050, particularly in developed and developing countries

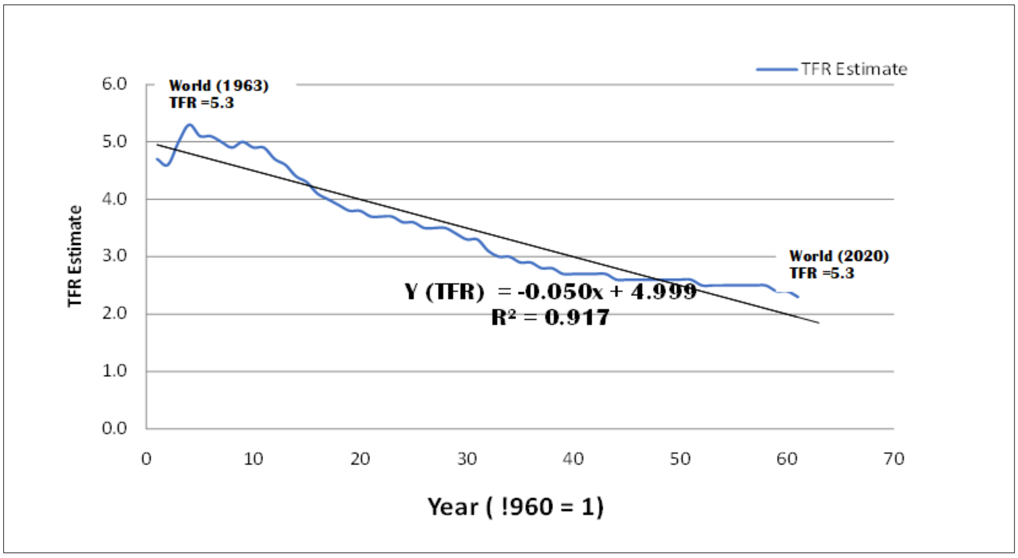

Figure 3 TFR estimate from 1960 to 2020

4. Conclusion

We have attempted in this paper to discuss a particular possibility of an ES to solve problems of complications primarily due to low and excessive birth weights at delivery by accurately estimating fetal parameters *(fetal weight, fetal age, conception date, and delivery date)* using ultrasound fetal biometric data. We have also emphasized the importance of the use of the ES in relation to the rapidly declining world total fertility rate (TFR). The primary goal of expert system research is to make expertise available to decision-makers and technicians who need answers quickly. There is never enough expertise to go around, and certainly it is not always available at the right place and time. But computers loaded with in-depth knowledge of specific subjects can bring a decade's worth of knowledge and a solution to a problem. If we must investigate and solve those ultrasonographic fetal biometry methods of estimation that have been described over the decades as complicated, labor-intensive, limited by suboptimal visualization of fetal structures, costly, and specially requiring trained personnel, we will have to build into the estimation the use of a computer wizard (an expert system). Otherwise, these problems might continue because many of us feel that they are too complex to solve. We submit that they are not.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors had no potential conflict of interest.

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