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## MACHINE LEARNING-BASED APPROACHES FOR MEASURING QUALITY OF MATERNAL, NEONATAL AND CHILD HEALTH SERVICES IN DEVELOPING COUNTRIES: A LITERATURE REVIEW

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### ABSTRACT

*High rates of maternal and neonatal mortality in developing countries are frequently linked to poor quality of healthcare provided to pregnant women and children. Quality measurement is one of the recommended step in improving the quality of maternal, neonatal and child health (MNCH) services. An effective quality measurement approach can enhance routine quality measurement and reporting hence improves MNCH quality. This study intended to review quality measurement approaches commonly used in developing countries and explore their effectiveness in quality measurement. Moreover the study highlights the capabilities of machine learning in facilitating effective quality measurement in MNCH. Review of academic journals, books and web pages related to MNCH was done. Knowledge related to quality measurement in MNCH, machine learning in MNCH and machine learning approaches for quality measurement was collected, organised and analysed. The review found that majority of existing quality measurement approaches are manual and paper based hence time consuming and resource inefficient. Furthermore, the use of machine learning in MNCH and machine learning based approaches for quality measurement in healthcare was observed. However, these approaches focus mainly on quality measurement in health services provided via the web pages and for the specific medical conditions. In this study the potential of machine learning in quality measurement has revealed and the proposal to use machine learning was presented. This would result into development of machine learning-based quality measurement approach suitable for resource-constrained countries such as Tanzania.*

**Keywords:** Machine Learning, Quality Measurement, Developing countries, Maternal Health Quality, Child Health Quality

**Paper type:** Research paper

**Type of Review:** Peer Review

### 1. INTRODUCTION

For the past two decades, tremendous efforts have been made to reduce mortality and morbidity among mothers and children under five years in developing countries(Alkema *et al.*, 2016). However, along with remarkable efforts, statistics show that about five million children under five years are still dying worldwide; majority of whom are from developing countries, particularly in sub-Saharan Africa(Hug Lucia, Sharrow David, 2018). With this adverse situation in mind, a number of interventions and programmes have been developed and implemented in an attempt to improve the provision and usage of maternal neonatal and child health (MNCH) services (Hug & Sharrow, 2018; Vesel *et al.*, 2015). Information and Communication Technology (ICT) is one among the initiatives employed to improve the

provision, utilization and access to MNCH services (Fedha, 2014; Fotso & Tsui, 2015; Nyamawe & Seif, 2014). Similar efforts have been undertaken in Tanzania, dedicated ICT tools and applications are used to provide MNCH services with the underlying assumptions of improving the well-being of pregnancy and the prospective newborn.

ICT applications such as mobile ultrasound, smart phone quantitative diagnosing solution, anemia and detection applications (Crispín *et al.*, 2016; Hackett *et al.*, 2018). ICT base projects like “wired-mothers” a project that links pregnant women with primary healthcare using mobile phone, “health pregnancy, health baby” a text messaging service that deliver high quality antenatal care (ANC) services mobile based tool for community health workers (CHWs) developed by world vision organization in Tanzania, “Chipatala Cha Pa Foni” a project that enhance knowledge on facility and home-based MNCH practices and client satisfaction with MNCH services in Balaka district in Malawi(Lund *et al.*, 2014; Mobile Alliance for Maternal Action, 2013). and websites like “Mama Ye” developed to address the challenges of maternity, labour, and child care in order to educate, empower and unite maternal and newborn health stakeholders (Van Lerberghe *et al.*, 2014) are among the initiatives undertaken to improve access and utilization of MNCH services. However, besides the increase in usage, access and coverage in MNCH services; hitherto, the rate of maternal and neonatal mortality remains high in many developing countries (WHO, 2015).

Empirical evidence reveals that the high mortality rate in developing countries have often been associated with poor quality of MNCH services provided (Austin *et al.*, 2014; Campbell *et al.*, 2016; Kahabuka *et al.*, 2011). The literature further reveals that there is high potential of minimizing death rate in developing countries if quality MNCH services will be readily available to pregnant women and children. For example, a situation analysis conducted by Manji (2009) shows that up to two thirds newborns could be saved if essential care services are readily available to mothers and babies in Tanzania. This means that the increased access and utilization of MNCH services alone is not enough to reduce the current maternal and neonatal deaths. Developing countries must systematically measure and improve the quality of MNCH services (Kruk *et al.*, 2016). This calls for effective quality measurement in order to improve quality MNCH services hence put an end to preventable maternal and neonatal mortality.

## 2. METHODS

This study reviewed the literature from academic journals, books and web pages related to MNCH care. The objective was to collect, organise and synthesize existing knowledge relating to quality measurement approaches and machine learning on approaches to measure MNCH quality. The reviewed literature focused on several works which have been done on machine learning in MNCH. Those works focused on prediction of diseases and conditions related to pregnancy and childbirth, prediction of maternal and neonatal death and morbidity etc. The findings from, literature are very useful in understanding the depth of quality measurement challenges and the ways to develop suitable approach to measure the quality of MNCH services in developing countries. Several databases such as Research Gates, Science Direct, IEEE Xplore and other computer science journals were searched. Machine Learning, Quality Measurement, Developing countries, Maternal Health Quality, Child Health Quality are keywords used in article searching and publication period taken into consideration is 1990 to 2019. On types of text searched, the study used documents and full length paper with abstract and keywords. Moreover in search items the study used journal articles, conference papers, workshop papers, projects reports and dissertations.

### 3. RESULTS

#### 3.1 Quality measurement in MNCH

Quality measurement is an important step in a process of improving quality of MNCH services. Essentially, it evaluates the performance of health services according to the acceptable standards in order to improve its quality (Akachi & Kruk, 2017). The process further tells whether health services provided have the required standards and can improve health and survival of women and children (Morris & Bailey, 2014). An analysis of the existing literature shows that in developing countries, mechanisms for assessing the quality of MNCH are relatively ineffective. For example, while ICT-based tools and mobile technology applications are used in the provision of MNCH services; quality measurement still depends on manual and paper-based approaches. The commonly used quality measurement approaches in developing countries include facility quality assessment tools such as Service Availability and Readiness Assessment (SARA); Quality of Prenatal and Maternal Care (QUALMAT); Hospital Care for Children; Service Provisional Assessment (SPA) and Rapid Health Facility Assessment (R-HFA) (Munos, Stanton, & Bryce, 2017; Saronga et al., 2017; WHO, 2015; WHO, 2014); Conceptual Frameworks such as Framework for Evaluation of Quality Care in Maternity Services (Hulton, Matthews, & Stones, 2000); Framework for Quality of Maternal and Newborn Health Care by World Health Organisation (WHO) (WHO, 2016); Framework for Quality Maternal and Newborn Care by Midwifery Association (Renfrew et al., 2014); Maternal, Newborn and Child Health Framework by International Federation of Red-Cross and Red Crescent Societies. Other approaches include Case Observations, Medical Records Review, Exit Interviews, Lot Quality Assurance Sampling and Demographic Health Surveys (DHS) (Anoke et al., 2015; Dettrick et al., 2016; Duysburgh et al., 2016; Simbar et al., 2012; Tumlinson et al., 2015). It was further observed that manual and paper-based quality measures are not only ineffective in measuring the quality of MNCH services but also fail to accommodate the new and innovative mechanisms used in providing MNCH services (Adirim, Meade, & Mistry, 2017).

#### 3.2 Machine Learning in MNCH

The current development in data science enhances the potentials of machine learning technology in healthcare domain. The use of machine learning in healthcare is increasingly becoming apparent coupled with mobile phones applications for MNCH (Chui et al., 2017). Previous studies have employed machine learning technology to predict medical conditions and diseases related to maternity to mitigate the inherent risks to mother and child. (Rodríguez et al., 2016) Used maternal clinical history to predict early severe maternal morbidity using logistic regression model. Moreover, (Poon et al., 2009) used logistic regression model to predict hypertensive disorders during pregnancy and predict risk of preeclampsia in pregnant women. The models predicted accurately over 90% and 95% detection rates, 5% and 10% false positive rates respectively. (Degninou, 2016), employed Lasso regression to develop an algorithm for predicting life-time risks of maternal death using world development indicators. The model predicted 0.0043% to 4.7250% death risk with mean score 0.527% (SD = 1.0433). Even (Nanda et al., 2011) developed a model that predicts gestational mellitus in the first trimester of pregnancy using bio-markers and some maternal features. Using logistic regression, the model accurately predicted about 74.1% to 20% false positive rate. In view of the previous analysis, it is evident that machine learning has successfully proved to be effective in different MNCH contexts such as providing the reasons behind preference of home birth among women (Jawad et al., 2015). This justifies the ability and the potential machine learning in enhancing quality measurement process in MNCH.

### **3.3 Machine learning in quality measurement**

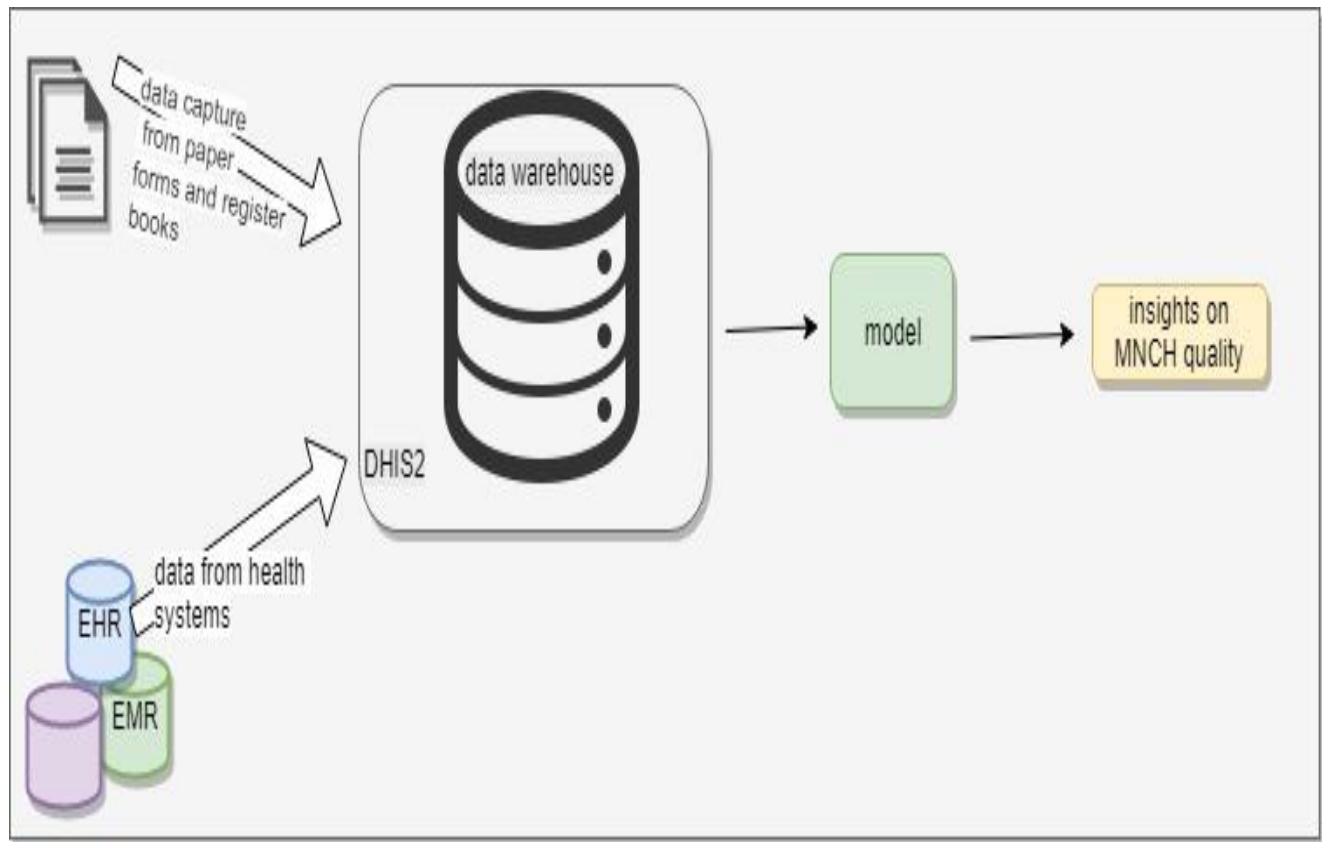
Natural language processing and machine learning techniques are widely used in developing machine learning models that assess the quality in healthcare. Several studies reported the use of machine learning to assessing the quality of care to patients and other healthcare seekers. Szlosek & Ferretti (2016) and Zhang *et al.*, (2014) developed the models that assess the quality of care provided in WebPages. Natural language and Naïve Bayes machine learning algorithm were used to identify evidence-based medical advices and treatment guidelines that are consistent with treatment provided in medical web pages (Al-jefri, Evans, & Ghezzi, 2017). Sondhi *et al.*, (2012) assessed the quality of medical web pages by classifying the reliability of the web pages based on the information contained and the web pages features such as page rank, links and commercial features. Moreover, machine learning techniques have been used in several scenarios related quality measurement in healthcare. For example; a study by (Greaves *et al.*, 2013) applied machine learning technique to detect poor quality of healthcare, Sako *et al.*, (2016), applied machine learning to address data accuracy and information integrity in digital health delivery and prediction of treatment response was done by Cao *et al.*, (2018). From the aforementioned analysis, it is evident that machine learning can potentially be used to assess quality in MNCH and considerably little efforts will be paid in employing machine learning as technique to measure the quality of MNCH care.

## **4. DISCUSSIONS**

Several observations have been made from the reviewed literature. First, majority of quality measurement approaches are manual and paper based. Being manual and paper based the approaches become time consuming and resource intensive. Moreover, the literature reveals that most of quality assessment approaches depends on data from Demographic Health Survey (DHS) and other community health surveys. These surveys normally are conducted in a certain time interval of five to ten years. Consequently, they need experts for data collection and data analysis. This impedes quality measurement process especially to developing countries which usually face budgetary constraints as well as shortage of human resource in health sector. The reviewed literature has further shown the potentials of machine learning in improving MNCH care. Studies by Munos *et al.*, (2017); Poon *et al.*, (2009);Rodríguez *et al.*, (2016); Jawad *et al.*, (2015); Lavecchia, (2014) for example have successfully used machine learning to predict medical conditions and diseases related to pregnancy and childbearing so as to mitigate the risks from both mother and prospect child. Also some machine learning algorithms have been developed specifically to assess the quality of healthcare provided via the web pages (Al-Jefri *et al.*, 2017; Sondhi *et al.*, 2012; Szlosek & Ferretti, 2016; Zhang *et al.*, 2014). Prompted by the need to improve MNCH quality and reduce maternal and neonatal deaths, there has been an increase push on measuring quality of care provided to pregnant women and children. Developing countries needs a robust quality measure to routinely measure and report on MNCH quality. Fortunately, machine learning has that potential to establish effective quality measurement approach to address the need for effective quality measurement approach (McMillan, 2017).

Additionally, the current use of Electronic Health Records Systems (EHR), Electronic Medical Records Systems (EMR) and the recently adopted District Health Information System (DHIS2) in developing countries contributes not only in improving collection and management of health data but also to improve the availability of quality data (Muinga *et al.*, 2018). Given the current development in ICT and availability of data it is worth arguing that it is a high time to use machine learning to measure the quality of health services provided to pregnant women and children in developing countries. (Powell, 2003) also observed that, it is advantageous to use data in measuring quality than other methods because the health data are readily available, it is easy and less cost to collect them. Significantly, machine learning can speed-up the development of quality measures approach and overcome the challenges like cost, labor

and the time spent associated with traditional quality measurement (McMillan, 2017). It is easier to integrate modern methods like machine learning into routine health services provision and it has been proven to provide valid and reliable results than other quality approaches.



**Figure 1: Proposed machine learning based approach for MNCH quality measurement**

## 5. CONCLUSION

Irrefutably, it is evidenced that the potentials for using machine learning to measure the quality of MNCH services is very high in developing countries. Given the availability of data through the use of EHRs that collect and store routine health data and the potentials machine learning in developing has effective quality assessment approaches in MNCH. Nevertheless, the existing machine learning approaches have neither assessed the quality of health services provided to pregnant women and children nor use data from routine care provision to assess the quality of health services provided. In view of the knowledge gap that exists, this study attempt to bridge this gap by proposing machine learning approach to measure the quality of MNCH services in the resource-constrained countries so as to reduce maternal and neonatal mortality rates.

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