Application of Big Data Analytics in Precision Medicine: Lesson for Ethiopia

MISGANAW TADESSE WOLDEMARIAM*
Information Science, Jimma University, Jimma
Jimma, Jimma Zone, Ethiopia
E-mail: misganawt2012@gmail.com

DANIEL GELAW ALEMNEH†
University of North Texas
Denton, Texas 76203, USA
†*E-Mail: Daniel.Alemneh@unt.edu*

Precision medicine is an emerging approach for disease treatment and prevention that considers individual variability in genes, environment, and lifestyle for each person. Big data analytics (BDA) using cutting-edge technologies helps to design models that can diagnose, treat and predict diseases. In Ethiopia, healthcare service delivery faces many challenges specifically in relation to prescribing the right medicine to the right patient at the right time. Thus, patients face challenges ranging from staying on treatment plans longer, and then leaving treatment, and finally dying of complications. Therefore, the aim of this paper is to explore the trends, challenges, and opportunities of applying BDA in precision medicine globally and take lessons for Ethiopia through a systematic literature review of 19 peer reviewed articles from five databases. The findings indicated that cancer in general, epilepsy, and systemic diseases altogether are areas currently getting big attention. The challenges are attributed to the nature of health data, failure in collaboration for data sharing, ethical and legal issues, interoperability of systems, poor knowledge skills and culture, and poor infrastructure. Development of modern technologies, experimental technologies and methods, cloud computing, Internet of Things, social networks and Ethiopia's government initiative to promote private technological firms could be an opportunity to use BDA for precision medicine in Ethiopia.

Key words: precision medicine, big data, big data analytics, Ethiopia

1. Introduction

1.1. Background

Precision medicine is not a one-size-fits-all approach, but a new area of disease treatment and prevention in which patients receive personalized medicine (Schaefer et al., 2019). It aims to combine comprehensive data (big data) collected over time about human genetics, environment and lifestyle to improve understanding and discovery of disease, support drug development, and provide appropriate therapies (Huang et al., 2016).

According to the Precision Medicine Initiative, precision medicine is an emerging approach for disease treatment and prevention that considers individual variability in genes, environment, and lifestyle for each person. This approach will help doctors and researchers predict more accurately which treatment and prevention strategies for a particular disease will work in which groups of people (United States National Library of Medicine, 2020).

Although precision medicine may appear to be a radical and innovative concept, it was first described around 2000 years ago in "The Yellow Emperor's Canon of Internal Medicine" (Roda et al., 2017). Precision medicine stands in contrary to the "one size fits all" concept, which expects researchers to develop disease treatment and prevention strategies for an "average" patient without much consideration for inter-individual variances (Roda et al., 2017). Unfortunately, when treating according to standardized therapeutics protocols, a given drug may be ineffective or inappropriate for a high proportion of patients, ranging from 40% to 70% or higher (Roda et al., 2017).

Medicines contributes to the improvement of quality of life and life expectancy by relieving symptoms, delaying disease progression, and curing diseases (Kefale et al., 2020). However, no drug is entirely harmless and can be associated with emergency department visits, hospitalization, in-patient, and outpatient care complications (Kefale et al., 2020). Medication Related Problems (MRPs) are unwanted effects that actually or potentially

interfere with health outcomes. They are significant causes of patient morbidity, mortality, economic loss, and contribute to overall pressure on the healthcare system (Kefale et al., 2020). MRPs include medication errors, adverse drug events, and adverse drug reactions (ADRs). The findings of Kefale et al. (2020) indicated that, almost half of the study participants had indication-related MRPs, while effectiveness and safety-related MRPs occurred among one in four patients. In addition to this, different socioeconomic, disease-related, medication-related, and healthcare-related variables contribute to the development of MRPs and ADRs.

Ethiopian government has developed health sector development plan (HSDP-I to HSDP-IV) and health sector transformational plan (HSTP) recently in order to mitigate challenges observed in healthcare service quality and access (Federal Ministry of Health [FMOH], 2015). Moreover, government and non-government supported initiatives are playing a significant role in adopting ehealth services like, mobile health, telemedicine, Electronic Health Record (EHR), Electronic Health Management Information System (eHMIS) etc., to excel service delivery which in turn generates a potential amount of electronic health record (FMOH, 2014). This shows a possible need for a new approach which can leverage the existing trends in a vast collection of data and get knowledge for quality clinical decision making and prescribing the right medicine for the right patient at the right time. Therefore, this issue can be solved by employing Big Data Analytics (BDA) on abundant health data across the country to reach for the anticipated better healthcare service delivery.

BDA is often a complex process of examining big data for information such as hidden patterns, correlations, market trends, and customer preferences that can help organizations make informed business decisions (Chai et al., 2021). Akal et al. (2019) defined BDA as the process of capturing and storing huge volumes of data which have different formats and are generated in high velocity. It also refers to the process of analyzing big data for the purpose of decision making, strategic planning, and policy formulation (Akal et al., 2019). BDA in healthcare involves analyzing large amounts of electronic data related to the health and well-being of patients. This data is so diverse that it is difficult to measure with conventional software or hardware (Galetsi et al., 2020). Therefore, such huge data can be easily analyzed and used for decision making purpose through applying BDA (Chai et al., 2021).

1.2. Problem Statement

In Ethiopia, BDA concepts and their implementation are either not known or left as insignificant in both government and non-government data intensive work environments. A case study conducted in four big data generating industries in Ethiopia namely, Ethiopian Telecommunication Corporation, Agricultural Transformation Agency, Payment systems, and Ethiopian educational networks indicated that, they are not using BDA for decision making due to lack of BDA awareness, data integration challenges, lack of skilled expertise in the areas, etc. (Akal et al., 2019).

Regarding precision medicine in Ethiopia, there is no research work done indicating the application of BDA in Ethiopian health sector in reaching for precision medicine or other healthcare service. According to WHO report, Ethiopia is among the countries which do not have a policy for the implementation of BDA and also BDA is not yet implemented in the health sector (WHO, 2016).

Developing countries like Ethiopia face challenges in providing quality medical diagnosis and treatment to patients. Gutema et al. (2018) and Gebretekle et al. (2018) noted that inability of medical professionals in prescribing precise medication for their patient is an indication of some of the challenges observed on a daily basis. The outcomes due to such medical errors could be fatal or sometimes result in an elongated medical attention which is uneconomical and may lead the patient to dropout from the treatment plan altogether (Endalemaw et al., 2020).

The aim of this study is to investigate the current trends, challenges and opportunities

of applying BDA in precision medicine globally and take lessons for Ethiopia through literature review of peer reviewed articles. This review is organized around the following research questions:

RQ1: What are the current trends in excelling the quality of medication using big data analytics?

RQ2: What challenges are observed in employing big data analytics for precision medicine?

RQ3: What opportunities are available for the successful implementation of big data analytics for precision medicine in Ethiopia?

2. Methodology

The literature review is organized with the main goal of excavating application of BDA in developed and developing countries focusing on its implementation, challenges and opportunities in order to identify concepts, tools, policies, and methods significant for the proper implementation of BDA in Ethiopia. For this particular study, systematic literature review (SLR) was employed to search for peer-reviewed journal articles from reputable sources. As Xiao & Watson (2017) presented, systematic literature review can be conducted within the framework of the following eight steps. These are (1) formulating the research problem; (2) developing and validating the review protocol; (3) searching the literature; (4) screening for inclusion; (5) assessing quality; (6) extracting data; (7) analyzing and synthesizing data; and (8) reporting the findings. The steps are pictorially presented in Figure 1.

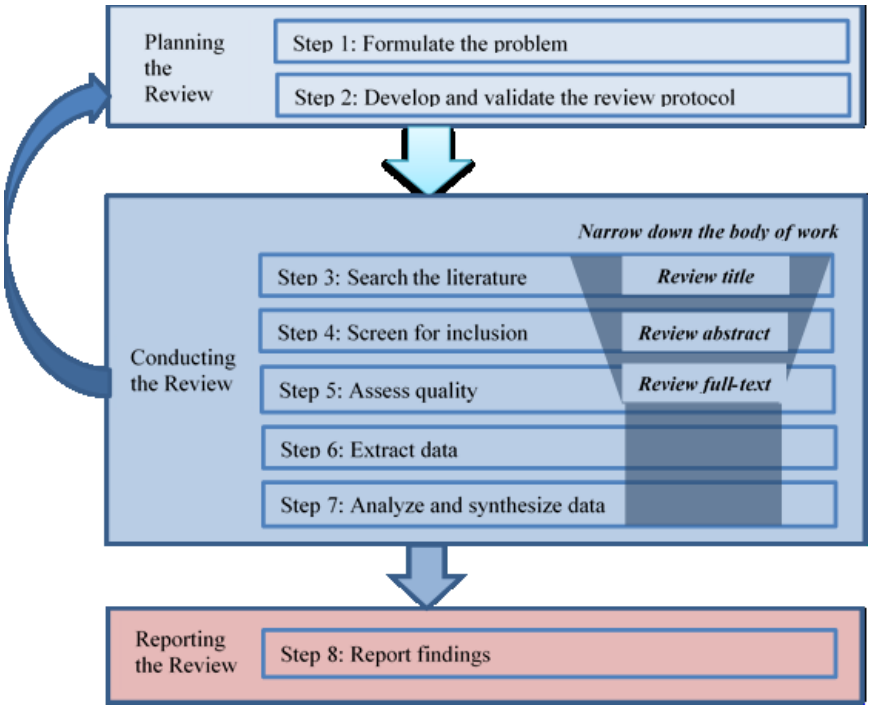

Fig. 1. Process of Systematic Literature Review

2.1. Planning the Review

Step 1: Formulate the Problem

The problem is well articulated and presented in (section 1.2.), which clearly presented the challenges in prescribing medicines in developing countries like Ethiopia, and this can be solved through the emerging technologies like BDA.

Step 2: Develop and Validate the review protocol

In this phase a review protocol is developed to systematically execute the review process. Thus, the review protocol was developed based the trends followed by different scholars to develop review protocol (Haghi Kashani et al., 2021; Mengist et al., 2020). Accordingly, we have prepared a protocol consisting of, search question, inclusion and exclusion criteria, database to be searched, search strategy, data extraction and analysis, declaration of interest and time frame.

Regarding search questions, as articulated under the section problem statement, the research is governed by three research questions with the overall goal of finding literatures dictating about implementation of BDA in precision medicine. Specifically, the questions addressed, implementation of BDA in precision medicine in the developed and developing world, identifying challenges and opportunities of BDA in precision medicine, and exploring opportunities to implement BDA for precision medicine in Ethiopia. In terms of inclusion and exclusion criteria, as presented in Haghi Kashani et al. (2021), criteria were set to pick significant articles for the identified problem. Table 1 presents the inclusion and exclusion criteria used for this literature review.

Table 1. Inclusion and Exclusion Criteria

Criteria	
Inclusion	1. Research article that presents challenges, opportunities, and practices of BDA in precision medicine 2. Research articles published from 2015 to 2022 3. JCR indexed journal articles 4. Peer-reviewed journal articles
Exclusion	1. Research articles that do not explicitly discuss about BDA and precision medicine 2. Books, book chapters, conference papers, symposiums, and non- English scripts 3. Short articles (less than six papers) 4. Commentaries or review articles

In relation to the databases to be searched, five electronic databases namely, Emerald, IEEE Xplore, PubMed, Science Direct, and Taylor and Francis were used based on their popularity in the area of interest.

In terms of the search strategy, keywords representing research questions were used to search articles which met the inclusion criteria. Whereas, data extraction was done through intensive reading of the articles and recording the findings in a sheet prepared for this particular purpose, analysis was done by putting ideas into already identified four themes.

The authors of this article declare that they have no conflict of interests.

2.2. Conducting the Review

Step 3: Search the Literature

Literature search is conducted using key words, "*big data analytics", "precision medicine"* and *"big data analytics and precision medicine"* on five identified electronic databases based on article's title. Titles were used to support the searching process and avoids the extra time to be wasted in reading the entire content. The search results were exported to an excel sheet for further understanding and support screening as shown in Table 2.

Step 4: Screen for Inclusion

In this SLR, article screening is done by manually reading the abstract and looking for association in terms of the research questions. Thus, articles matched with the inclusion criteria and having proximity to the research topic are selected to undergo the SLR. Accordingly, based on the proximity to the research topic and criteria for choosing each paper, 19 published articles which correlated with the criteria were selected to undergo an in-depth review. The summary of selected articles is presented in Table 2.

Table 1. Inclusion and Exclusion Criteria

Database	Search Result	Selected Articles
Emerald	23	-
IEEE Xplore	7	3
PubMed	47	13
Science Direct	38	3
Taylor and Francis	314	-

Step 5: Assess Quality

The authors have critically reviewed each of the articles in the final list to confirm quality. Accordingly, all of the 19 articles have strong relationship with the research topic and have good quality.

Step 6: Extract Data

The data from each of the articles was extracted through a rigorous review and organized in a form of annotated bibliography. Thus, a bibliography for all of the 19 articles was prepared to support the subsequent analysis and synthesis.

Step 7: Analyze and Synthesize Data

The data organized in annotated bibliography was analyzed based on the main goal of the SLR. After getting the concept behind each of the selected articles and considering the research questions, data was synthesized to build up sound and significant answers for each question and overall achieve the aim of the literature review.

2.3. Reporting the Review

Step 8: Report Findings

The findings of this systematic literature review are presented in the discussions and conclusion sections of this paper. Further, the authors made recommendations for all the concerned bodies for the proper implementation of BDA in precision medicine based on the findings of the paper.

3. Literature Review

The literature review consists of four sections, namely: overview of precision medicine, trends of BDA in precision medicine, challenges and opportunities of applying BDA in precision medicine. Further, discussion, conclusion and recommendations are included based on the findings of the SLR.

3.1. Overview of Precision Medicine

Precision medicine in its broad sense is not a new approach, where medical doctors have been delivering the usual therapies and preventative care that will best suit the particular patient considering all relevant individual-oriented factors (Schaefer et al., 2019). Though, medical diagnosis and treatment capabilities are growing, the need for a better care and treatment is always a question for humankind. Precision medicine promotes transformation in healthcare, medical decisions, treatments, practices and products customized to a subgroup of patients based on understanding of individual genes, environment and lifestyle (Naithani et al., 2021).

Precision medicine which was announced by the former president of the United States, Barack Obama in 2015, has been identified as a promising advancement to impact automated medical decision making (Ghitza, 2015). It aims to establish a new research framework accelerating the innovation of the right treatment, for the right patient, at the right time, (Sadat Mosavi & Filipe Santos, 2020). The core of precision medicine is the analysis, identification and verification of biomarkers for a large sample population and specific disease types with the help of cutting-edge technologies such as genome and proteome determination, so as to accurately find the causes of diseases and therapeutic targets, (Vargas & Harris, 2016). The identification of biomarkers lays a necessary foundation for precise medicine.

Naithani et al. (2021), also noted that precision medicine has a wide range of applications in both diagnostic and therapeutic fields which include: development of new omics signature-based biomarkers; development of pharmacotherapy based on pharmaco-omics; precision medicine in oncology; precision medicine in chronic disorders; precision medicine in emergency care; and precision medicine in infectious diseases.

Precision medicine is challenged by its nature of data-intensiveness; hence it requires large volumes of data which needs to be collected and analyzed which is not only costly but also needs labor and technical knowhow. In addition to this, data anonymization, security, ethical challenges, noise, and turnaround time of data analysis are critical issues to be considered during implementation of precision medicine, (Naithani et al., 2021). The ultimate goal of precision medicine is to provide rational pharmacotherapy, i.e. to prescribe the right drug to the right patient in the right dose at the right time avoiding harm to the patient (Naithani et al., 2021).

3.2. Trends of BDA in Precision Medicine

The concept of big data refers to sets of data with a scale and complexity that enforces the use of dedicated analytical and statistical approaches, though exact and universally accepted definition does not exist (Alonso et al., 2017). Whereas, in the case of biomedicine, big data include large-volume and highly diverse biological, genetic, clinical, environmental and lifestyle information collected from single individuals as well as large cohorts in relation to their disease and/or wellness status at one or several time points (Auffray et al., 2016). As Wu et al. (2017) noted, big data in healthcare constitutes, large omics data collected through next generation sequencing technology and mass spectrometry, and electronic health record (EHR) which is collected through patient-doctor interaction in healthcare institutions.

Big data in healthcare and medicine refers to various large and complex data, which are difficult to analyze and manage with traditional software or hardware. BDA covers integration of heterogeneous data, data quality control, analysis, modeling, interpretation and validation, (Ristevski & Chen, 2018). Application of BDA generates comprehensive

knowledge discovered from the available huge amount of data which provides comprehensive benefits to the patients, clinicians, and health policy makers (Ristevski & Chen, 2018).

Ristevski and Chen (2018) noted that, applications of BDA can enhance the patient-based service to detect spreading diseases earlier, generate new insights into disease mechanisms, monitor the quality of the medical and healthcare institutions as well as provide better treatment methods. BDA can be used for treating different types of diseases from infectious to complications like cancer. As Gameiro et al. (2018) noted, cancer and psychiatry have the lead in using precision medicine to provide tailored medicine for patients based on their unique characteristics.

According to Shah and Masters (2020), lung cancer is the leading cause of cancer death in men and women in the United States and more than 80% of these patients have non-small cell lung cancer. The authors mentioned that, in recent days due to advance in technology, immunotherapy has made possible to treat patients even those whose cancer stage reached stage IV.

In a study conducted by Prabhakaran et al. (2020), there is a clear finding indicating a critical progress within the advancement of precision medicine for colorectal carcinoma, impacting areas of screening, treatment, and potentially prevention. Advancement in molecular techniques have made it possible for far better selection of patients for treatments and it is vital that mutational investigation is performed at the time of diagnosis to guide treatment. Striano and Minassian (2020) noted that, due to advances in next generation sequencing, the previously known medications for epilepsy which are anti-seizure drugs are being replaced by personalized therapeutic approaches (precision medicine). Hence, the genetic tests could forward directions for the genetic causes of several epileptic conditions which have been unveiled and remarkably improved our knowledge on the pathogenesis of epileptogenesis.

Pinker et al. (2018) noted that, radiogenomics can be used to identify breast tumor status using genetic and radiomic data by correlating with individual's life style and environmental variables to aid the treatment and prevention of breast cancer. In a study conducted by Song et al. (2020), precision medicine is used to treat diseases of motor system, circulatory system, respiratory system, urinary system, endocrine system, nervous system, and reproductive system as well as cancer. Moreover, precision medicine sets a conducive environment for efficient drug development and reduces the cost of development.

3.3. Challenges of Applying BDA in Precision Medicine

The health data by itself creates challenges for the success of precision medicine. Some of these challenges hindering BDA are collecting large amount of data, heterogeneity of data sources, noise of experimental omics data, variety of experimental techniques, environmental conditions, and biological nature (Ristevski & Chen, 2018). The issues indicated above should be carefully analyzed before combining such heterogeneous data and before employing machine learning methods.

These inadequacies might lead to the lack of quality of some of the data points, such as missing values or outliers. In spite of these downsides of the omics data (i.e. genomics, epigenomics, microbiomics, lipidomics, proteomics, transcriptomics etc.), EHRs data are exceptionally impacted by the staff who entered the patient's information, which can lead to entering missing values, inaccurate data as a result of mistakes, misconception or wrong understanding of the original data (Wu et al., 2017).

Pastorino et al. (2019) indicted that, challenges in BDA are altogether credited to failure in collaboration for data sharing, ethical and legal issues, data heterogeneity, data security, analytical flows in analyzing data and lack of suitable infrastructure for data storage and computation. One of the biggest challenges to carry out precision medicine experiments is providing adequate protection for private health data while sharing data among stakeholders (hospitals, research organizations, pharmaceutical companies,

insurance companies, and ownership of cloud servers) (Sethu et al., 2020). Precision medicine is also challenged by heterogeneous data integration and joint processing to support new knowledge discovery. In significance to precision medicine advances, genomic analysis and molecular profiling are a computationally intensive task (Panayides et al., 2019).

3.4. Opportunities of Applying BDA in Precision Medicine

Rapid development of the emerging information technologies, experimental technologies and methods, cloud computing, Internet of Things, social networks supply large volume of generated data which is growing tremendously in numerous research fields, (Ristevski & Chen, 2018). Innovation of new platforms, tools and methodologies for storing and structuring data has made collecting data from EHRs, social media, patient summaries, genomic and pharmaceutical data, clinical trials, telemedicine, mobile apps, sensors and information on well-being, behavior and socio-economic indicators to be easier. Healthcare professionals can benefit from such Big Data immensely (Pastorino et al., 2019).

Although some of the hardest challenges for computing systems are focused on extreme data analytics and data-intensive simulations such as streaming data analysis and virtual patient design; machine learning on high dimensional data represents a prevalent concern. As a result, advanced machine learning methods such as deep learning and platforms for cognitive computing represent the future toolbox for data-driven analysis of biomedical big data (Cirillo & Valencia, 2019).

According to Song et al. (2020), in the future, with the decrease of gene sequencing cost, the application of metagenomic sequencing and the progress of molecular pathology epidemiology will boost the development of precision medicine. In cognizant to the above, investment over new technology and human capital are essential for the successful implementation of BDA in precision medicine, (Pastorino et al., 2019).

4. Discussion

In our study, the SLR showed insights on the current status of precision medicine, the challenges faced by the developed countries while implementing BDA and associated opportunities that would be exploited to further grow a rich BDA in the area of precision medicine. Many scholars presented, precision medicine is being utilized in the areas of diagnosis, treatment and prediction of disease outcomes, (Naithani et al., 2021; Schaefer et al., 2019; Vargas & Harris, 2016). Nowadays, precision medicine is used in treating diseases ranging from infectious to chronic diseases, cancer, mental disease etc. (Gameiro et al., 2018). Developed nations are taking advantage of Big Data to solve problems which were impossible to manage using human cognitive skill. Developing countries are also looking forward to exploit big data analytics to alter health related issues.

Many of the challenges in implementing precision medicine are associated with the data itself. Hence, big data comprises data which is characterized by: volume, value, velocity, variety, veracity, and variability. Data quality is the first challenge which might lead to making wrong clinical decisions if not taken with great care (Wu et al., 2017). Integrity of data is another challenge whenever sharing and storing data (Pastorino et al., 2019).

Infrastructure which is used for capturing, storing, analyzing and sharing big data demands a big budget and seems challenging for developing or under developed countries. Initiatives in developed countries are building platforms for storing, processing and sharing data. They are also providing a software solution to manage data in distributed manner. This trend can also be used by developing countries like Ethiopia to exploit BDA so as to leverage its benefits.

Human capital is very essential for the successful implementation of BDA in precision medicine. It all begins from equipping physicians with the knowledge of recording the correct patient data in the right format into the right database and extends to applying appropriate analysis techniques to generate knowledge by the data scientists. Therefore,

trainings for every stakeholder like, physicians, data scientists, IT professionals, etc. to fill the knowledge and skill gap could potentially affect the effective implementation of BDA in developing countries.

BDA needs a policy to guide its implementation and to provide the necessary support expected from each stakeholder. In the case of Ethiopia, Big Data analytics has no policy for its implementation and administration (WHO, 2016). Moreover, advancement in computing, high band-width data transmission, cloud computing, sophisticated machine learning methods and the like will be potential enablers for the growth of BDA in developed and developing countries (Ristevski & Chen, 2018).

In Ethiopia, the government's withdrawal of a law which has been disallowing private telecommunication firms to invest and operate has brought opportunities to attract global telecom firms to invest and build their own network infrastructure which could enhance the existing Ethio-Telecom network facilities. This would potentially help the health sector to build a national data repository on a cloud-based storage; systems capable of collecting and storing data across the country; accessing global databases for different types of data for research and other purposes; and promote data and knowledge sharing among institutions and many more. Further, the fast-growing health data and global push factor to use BDA would be the opportunities for implementing big data analytics specially to support the attempt to provide tailored clinical services (precision medicine) to the people of Ethiopia. The infancy or total absence of BDA in the health sector of Ethiopia would be both a challenge and an opportunity. The challenge is, it requires a lot of budget to setup the infrastructure (hardware and software) needed for the successful implementation of BDA. Whereas, all the challenges learned from countries which already built and using BDA based systems would be an opportunity to design and develop such kind of systems at relatively lower cost and with better understanding of the problem domain. Further, policies, strategies and methods can be easily adopted from the pioneers and even through collaborations technical support, knowledge, skill transfer and resource support could be obtained.

5. Conclusion

Precision medicine is an emerging area for disease treatment and prevention whereby a patient receives personalized medicine in contrast to a one size fits all approach. It aims to combine big data collected over time about an individual's genetics, environment, and lifestyle, to advance disease understanding and interception, aid drug discovery, and ensure delivery of appropriate therapies. The core of precision medicine is the analysis, identification and verification of biomarkers for a large sample population and specific disease types with the help of cutting-edge technologies such as genome and proteome determination, so as to accurately find the causes of diseases and therapeutic targets. The identification of biomarkers lays a necessary foundation for precision medicine.

BDA can enhance patient-based services, to detect spreading diseases earlier, generate new insights into disease mechanisms, monitor the quality of the medical and healthcare institutions as well as provide better treatment methods. These days, BDA is being used for treating different types of diseases ranging from infectious to complicated like, cancer and psychiatry. Many scholars indicated that BDA is being used for treating lung cancer, colorectal cancer, epilepsy, breast cancer, and in general systemic diseases of motor, circulatory, respiratory, urinary, endocrine, nervous, and reproductive systems.

The major challenge in applying BDA in precision medicine is attributed to healthcare data. Some of the challenges of healthcare data are collecting large amount of data; heterogeneity of data sources; noise; variety of experimental techniques; and environmental conditions and biological nature of healthcare data. Further, failure in collaboration for data sharing, ethical and legal issues, data protection, analytical flows in analyzing data and lack of appropriate infrastructure for data storage and computation poses a challenge when applying BDA for precision medicine.

Rapid development of the emerging information technologies, experimental

technologies and methods, cloud computing, Internet of Things, social networks supply large volume of generated data which is growing tremendously in numerous research fields. Innovation of new platforms, tools and methodologies for storing and structuring data has made collecting data from EHRs, social media, patient summaries, genomic and pharmaceutical data, clinical trials, telemedicine, mobile apps, sensors and information on well-being, behavior, and socio-economic indicators is becoming easier. Advanced machine learning methods such as deep learning and platforms for cognitive computing represent the future toolbox for data-driven analysis of biomedical big data. In the future, with the decrease of gene sequencing costs, the application of metagenomic sequencing and the progress of molecular pathology epidemiology will boost the development of precision medicine.

In Ethiopia, the government's withdrawal of a law which has been disallowing private telecommunication firms to invest and operate has brought opportunities to attract global telecom firms to invest and build their own network infrastructures which could enhance the existing Ethio-Telecom network facilities. Further, the fast-growing health data and global push factor to use BDA would be the opportunities for implementing BDA in Ethiopia specifically to support the attempt to provide tailored clinical services (precision medicine).13

6. Recommendations

Based on the major findings identified from the literature review the following recommendations are forwarded for concerned bodies.

- The government of Ethiopia should develop a policy framework to govern big data in healthcare institutions with respect to using it for building automated clinical decision support systems using BDA.
- Infrastructure is key for the successful implementation of BDA in any sector. Therefore, government should give due attention to equip and maintain hardware and software resources for health institutions.
- The Federal Ministry of Health should collaborate with countries having better experience in using health data for decision support purposes.
- The Federal Ministry of Health should prepare standard guidelines and frameworks to collect, store and share health data across health institutions for research and decision support purposes.
- Doctors, nurses, and data clerks should record and store health data correctly thinking that data is significant for future data-driven activities.
- Researchers and data scientists should give due attention to work on healthcare big data to solve public health problems in terms of disease prevention, treatment and prediction.
- Government and private healthcare institutions and research centers should plan and implement big data analytics strategies to enhance service delivery which brings quality patient care and treatment outcomes.

References

Akal, T. D., Beshah, T., Sackmann, S., & Negash, S. (2019). Challenges of identifying and utilizing big data analytics in a resource-constrained environment: In the case of Ethiopia. *IFIP Advances in Information and Communication Technology*, 234–254. https://doi.org/10.1007/978-3-030-20671-0_17

Alalawneh, A. A., & Alkhatib, S. F. (2020). The barriers to big data adoption in developing economies. *The Electronic Journal of Information Systems in Developing Countries*, *87*(1). https://doi.org/10.1002/isd2.12151

Alonso, S. G., de la Torre Díez, I., Rodrigues, J. J., Hamrioui, S., & López-Coronado, M. (2017). A systematic review of techniques and sources of big data in the healthcare sector. *Journal of Medical Systems*, *41*(11). https://doi.org/10.1007/s10916-017-0832-2

Auffray, C., Balling, R., Barroso, I., Bencze, L., Benson, M., Bergeron, J., Bernal-Delgado, E., Blomberg, N., Bock, C., Conesa, A., Del Signore, S., Delogne, C., Devilee, P., Di Meglio, A., Eijkemans, M., Flicek, P., Graf, N., Grimm, V., Guchelaar, H.-J., … Zanetti, G. (2016). Making sense of big data in health research: Towards an EU action plan. *Genome Medicine*, *8*(1). https://doi.org/10.1186/s13073-016-0323-y

Chai, W., Labbe, M., & Stedman, C. (2021, December 14). *What is Big Data Analytics and why is it important?* Search Business Analytics. Retrieved April 26, 2022, from https://www.techtarget.com/searchbusinessanalytics/definition/big-data-analytics

Cirillo, D., & Valencia, A. (2019). Big Data Analytics for Personalized Medicine. *Current Opinion in Biotechnology*, *58*, 161–167. https://doi.org/10.1016/j.copbio.2019.03.004

Endalamaw, A., Dessie, G., Biresaw, H., Belachew, A., Amare, D., Workineh, Y., Birhanu, M., Belay, G. M., Wondim, A., Wubneh, C. A., Birhanu, Y., Asmare, Y., Wagnew, F., Minuye, B., Kefale, D., Nigussie, Z., & Habtewold, T. D. (2020). Medication errors in Ethiopia: Systematic review and meta-analysis. https://doi.org/10.21203/rs.3.rs-35808/v1

FMOH. (2014). *Ethiopian National eHealth Strategic.* Ethiopian National e-Health Strategy. Retrieved Feb 20, 2022, from https://www.who.int/goe/policies/ethiopian_ehealth_strategy2014.pdf?ua=1

FMOH. (2015). Ethiopia Health Sector Transformation Plan (2015/16-2019/20). Retrieved Feb 20, 2022, from https://www.globalfinancingfacility.org/ethiopia-health-sector-transformation-plan-201516-201920

Galetsi, P., Katsaliaki, K., & Kumar, S. (2020). Big Data Analytics in health sector: Theoretical Framework, techniques and prospects.International *Journal of Information Management*, *50*, 206–216. https://doi.org/10.1016/j.ijinfomgt.2019.05.003

Gameiro, G. R., Sinkunas, V., Liguori, G., & Auler-Júnior, J. O. (2018). Precision medicine: Changing the way we think about Healthcare. Clinics, 73. https://doi.org/10.6061/clinics/2017/e723

Gebretekle, G. B., Haile Mariam, D., Abebe, W., Amogne, W., Tenna, A., Fenta, T. G., Libman, M., Yansouni, C. P., & Semret, M. (2018). Opportunities and barriers to implementing antibiotic stewardship in low and middle-income countries: Lessons from a mixed-methods study in a tertiary care hospital in Ethiopia. *PLOS ONE*, *13*(12). https://doi.org/10.1371/journal.pone.0208447

Ghitza, U. E. (2015). A commentary on "A new initiative on precision Medicine". *Frontiers in Psychiatry*, *6*. https://doi.org/10.3389/fpsyt.2015.00088

Gutema, G., Håkonsen, H., Engidawork, E., & Toverud, E.-L. (2018). Multiple challenges of antibiotic use in a large hospital in Ethiopia – a ward-specific study showing high rates of hospital-acquired infections and ineffective prophylaxis. *BMC Health Services Research*, *18*(1). https://doi.org/10.1186/s12913-018-3107-9

Haghi Kashani, M., Madanipour, M., Nikravan, M., Asghari, P., & Mahdipour, E. (2021). A systematic review of IOT in Healthcare: Applications, techniques, and Trends. *Journal of Network and Computer Applications, 192*, 103164. https://doi.org/10.1016/j.jnca.2021.103164

Huang, B. E., Mulyasasmita, W., & Rajagopal, G. (2016). The path from Big Data to Precision Medicine. *Expert Review of Precision Medicine and Drug Development, 1*(2), 129–143. https://doi.org/10.1080/23808993.2016.1157686

Kefale, B., Degu, A., & Tegegne, G. T. (2020). Medication-related problems and adverse drug reactions in Ethiopia: A systematic review. *Pharmacology Research & Perspectives*, *8*(5). https://doi.org/10.1002/prp2.64115

Mengist, W., Soromessa, T., & Legese, G. (2020). Method for conducting systematic literature review and meta-analysis for Environmental Science Research. *MethodsX*, *7*, 100777. https://doi.org/10.1016/j.mex.2019.100777

Naithani, N., Atal, A. T., Tilak, T. V. S. V. G. K., Vasudevan, B., Misra, P., & Sinha, S. (2021). Precision medicine: Uses and challenges. *Medical Journal Armed Forces India*, *77*(3), 258–265. https://doi.org/10.1016/j.mjafi.2021.06.020

Panayides, A. S., Pattichis, M. S., Leandrou, S., Pitris, C., Constantinidou, A., & Pattichis, C. S. (2019). Radiogenomics for precision medicine with a big data analytics perspective. *IEEE Journal of Biomedical and Health Informatics*, *23*(5), 2063–2079. https://doi.org/10.1109/jbhi.2018.2879381

Pastorino, R., De Vito, C., Migliara, G., Glocker, K., Binenbaum, I., Ricciardi, W., & Boccia, S. (2019). Benefits and challenges of Big Data in Healthcare: An overview of the European initiatives. *European Journal of Public Health*, *29*(Supplement_3), 23–27. https://doi.org/10.1093/eurpub/ckz168

Pinker, K., Chin, J., Melsaether, A. N., Morris, E. A., & Moy, L. (2018). Precision Medicine and radiogenomics in breast cancer: New approaches toward diagnosis and treatment. *Radiology*, *287*(3), 732–747. https://doi.org/10.1148/radiol.2018172171

Prabhakaran, S., Leong, J., Petrelli, N. J., & Khatri, V. P. (2020). Precision medicine in colorectal surgery. *Surgical Oncology Clinics of North America, 29*(1), 23–34. https://doi.org/10.1016/j.soc.2019.09.001

Ristevski, B., & Chen, M. (2018). Big Data Analytics in medicine and Healthcare. *Journal of Integrative Bioinformatics*, *15*(3). https://doi.org/10.1515/jib-2017-0030

Roda, A., Michelini, E., Caliceti, C., Guardigli, M., Mirasoli, M., & Simoni, P. (2017). Advanced bioanalytics for precision medicine. *Analytical and Bioanalytical Chemistry*, *410*(3), 669–677. https://doi.org/10.1007/s00216-017-0660-8

Sadat Mosavi, N., & Filipe Santos, M. (2020). How prescriptive analytics influences decision making in Precision Medicine. *Procedia Computer Science*, *177*, 528–533. https://doi.org/10.1016/j.procs.2020.10.073

Schaefer, G. O., Tai, E. S., & Sun, S. (2019). Precision Medicine and Big Data. *Asian Bioethics Review*, *11*(3), 275–288. https://doi.org/10.1007/s41649-019-00094-2

Sethu, S. G., Nair, R. S., & Sadath, L. (2020). Big Data in precision medicine and its legal implications. 2020 IEEE 15th International Conference on Industrial and Information Systems (ICIIS). https://doi.org/10.1109/iciis51140.2020.9342723

U.S. National Library of Medicine. (2020, September 17). Precision medicine: Medlineplus genetics. *MedlinePlus*. Retrieved Feb 17, 2022, from https://medlineplus.gov/genetics/understanding/precisionmedicine

Vargas, A. J., & Harris, C. C. (2016). Biomarker development in the Precision Medicine Era: Lung Cancer as a case study. *Nature Reviews Cancer, 16*(8), 525–537. https://doi.org/10.1038/nrc.2016.56

WHO. (2016). Who | Ethiopia: Data and statistics. Country Context Indicators. Retrieved Feb 10, 2022, from https://www.who.int/gho/countries/eth/data/en/

Wu, P. Y., Cheng, C. W., Kaddi, C. D., Venugopalan, J., & Hoffman, R. (2017). –OMIC and electronic health record Big Data Analytics for Precision Medicine. *IEEE Transactions on Biomedical Engineering*, *64*(2), 263–273. https://doi.org/10.1109/tbme.2016.2573285

Xiao, Y., & Watson, M. (2017). Guidance on conducting a systematic literature review. *Journal of Planning Education and Research*, *39*(1), 93–112. https://doi.org/10.1177/0739456x17723971