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REVIEW

Role of biomarkers in disease management and drug development in Africa: A narrative review

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Abstract

Biomarkers are quantifiable components in the body or its byproducts that can be used to evaluate human health or pathogen development. This review aimed to explore and evaluate the utilization, challenges, and prospects of biomarkers in enhancing drug development in Africa. We searched for relevant articles in online databases, such as PubMed, Science Direct, and Google Scholar, covering the period from 2013 to 2024. The use of biomarkers can be traced back to the 1800s when they were initially referred to as surrogate markers and later as surrogate endpoints. Biomarkers are specific molecules or cells in the body that serve as indicators of underlying biological processes, aiding in disease diagnosis or measuring pharmacological responses to therapy. Diagnostic biomarkers are biomolecules that indicate the presence of diseases or help identify specific disease subtypes in individuals. Examples of biomarkers for common diseases, such as malaria, include *Plasmodium falciparum* lactate dehydrogenase, histidine-rich protein 2, and hemozoins; for colorectal cancer, biomarkers include Rat Sarcoma, microsatellite instability, human epidermal growth factor receptor 2, consensus molecular subtypes, and Circulating tumor DNA/Circulating tumor cells. These biomarkers guide targeted therapy and adjuvant chemotherapy approaches by allowing for patient stratification and determining which patients would benefit from adjuvant treatment. Overcoming challenges such as cost-effectiveness and regulatory approval is crucial. Despite initial financial and logistical constraints, these efforts will ultimately result in significant improvements in efficiency.

Keywords: Biomarkers; African region; Drug development; Disease management

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1. Introduction

Biomarkers are measurable elements, structures, or functions in the body, including their metabolites, that can help determine their effects on human health or disease development.[1] Biomarkers, or biological markers, are among the characteristics that

can be objectively measured and evaluated as potential indicators of any normal or abnormal pathophysiological process or pharmacological response to a given treatment.[1] They can include proteins, genes, or other types of biomolecules.[2] Biomarkers are essential for drug discovery, development, and personalized healthcare because they provide information on diagnosis, prognosis, and therapeutic response.[2] They also help identify possible therapeutic targets, assess the efficacy and safety of pharmaceutical products, and facilitate monitoring of disease progression and treatment outcomes.[2]

Biomarkers can be classified into several categories such as safety, pharmacodynamic, therapeutic, prognostic, and diagnostic.[2] The domains of cancer classification and biomarker discovery are increasingly utilizing machine learning (ML) approaches, which facilitate the identification of novel biomarkers for personalized therapy programs.[2] Identifying potential targets and evaluating their efficacy and safety are essential for the search and development of new drugs.[2] It is crucial to eliminate certain barriers and restrictions in traditional drug development approaches, such as the need to identify new risk factors, initial diagnostic indicators, or alternative therapeutic methods. Conventional drug development procedures often encounter difficulties in addressing safety and efficacy challenges, such as significant drug accumulation in organs beyond the target or inadequate accumulation at target sites during the later phases of this process.[3] Using biomarkers in the development of medicinal products offers several advantages. First, biomarkers accelerate the development of new medicines by providing unbiased information on normal biological processes, diseases, and pharmacological responses to treatment.[4] These biomarkers can optimize clinical benefits through specific therapies by supporting the co-development of diagnostics and identifying responsive populations.[5]

Biomarker research has advanced significantly in several areas, including cancer detection, chronic pain, and optical biosensors.[6] *UBE2C*, a gene that is differentially expressed in 28 types of cancer, plays a crucial role in both overall survival (OS) and disease-free survival for patients with many of these cancers. Moreover, assessing *UBE2C*'s diagnostic value and its correlation with various immune-related signatures could establish it as a reliable biomarker for cancer diagnosis. *UBE2C* may also serve as a therapeutic gene that enhances treatment responses and OS for cancer patients, making it a promising target for future cancer drugs.[7] Significant progress has been made in the field of cancer diagnostics, including the development of robust, reliable, and cost-effective cancer diagnostic tools.[6] Improving methods for detecting biomarkers could significantly enhance health outcomes. Incorporating biomarker approaches into drug development processes could lead to faster approvals, lower development costs, and better outcomes for patients. By using biomarkers for individualized treatment, researchers can identify patients who are more likely to respond to specific medicinal products and tailor their treatment to meet individual needs.[8] This approach will lead to increased treatment options and improved patient care. In addition, biomarkers can identify individuals at higher risk for adverse reactions to certain medicinal products, enabling more efficient and effective treatments.[9] A recent study on biomarkers for identifying bacterial versus non-bacterial febrile infections in African children has yielded positive outcomes.

Researchers found angiotensinogen (AGT) to be a promising plasma protein biomarker that accurately identified bacterial infections in febrile children from a low-income area in Kenya. Contrary to C-reactive protein (CRP), AGT demonstrated superior performance in differentiating invasive bacterial infections from febrile malaria episodes and in distinguishing bacterial infections from those caused by viruses.[10] The Royal Marsden Hospital (RMH) score has proven effective in various cancers, such as colorectal cancer (CRC), sarcoma, and non-small-cell lung cancer.[7] It serves as a valuable biomarker for both clinical trial participants and as a prognostic marker in real-world contexts.[7] The baseline RMH score independently predicts OS and progression-free survival (PFS) in patients with extensive-stage small-cell lung cancer, being the sole independent prognostic factor for PFS.[7] A large cohort study involving over 100,000 real-world patients confirmed a shorter OS in those with high RMH scores. These results underscore the RMH score's potential as a prognostic tool for both clinical trial selection and real-world clinical applications.[7] Hearing loss linked to immune checkpoint inhibitor (ICI) treatment is generally reversible in melanoma patients and is often accompanied by other immune-related adverse events.[11] It also correlates with a high response rate to ICIs. As ICIs are increasingly used in earlier treatment stages and adjuvant settings, the number of survivors experiencing ICI-related hearing loss is expected to increase.[11] In this review, we aimed to explore and evaluate the utilization, challenges, and prospects of biomarkers in enhancing drug development in Africa.

2. Methods

2.1. Literature search

A comprehensive literature search of many key databases, including PubMed, Scopus, and Web of Science, was conducted for this narrative review. Search terms included

"Biomarkers," "African disease," "drug development," and "precision medicine."

2.2. Methods

2.2.1. Inclusion criteria

English-language articles published between 2010 and 2024 that focused on biomarkers in African disease and drug development were included. This specifically encompassed original research articles, reviews, case studies, cross-sectional studies, randomized controlled trials, non-randomized controlled trials, and case reports, with a particular emphasis on human populations, primarily those prevalent in Africa or of relevance to African populations.

2.2.2. Exclusion criteria

Non-English-language articles, publications before 2010 or after 2024, studies not focused on biomarkers or African disease/drug development, editorials, letters to the editor, case reports, non-human studies or research not centered on African populations, diseases not relevant to Africa or lacking biomarker focus, and articles without available full text were excluded. Duplicate publications or studies with overlapping data were also excluded.

3. Results

3.1. Biomarkers based on applications

3.1.1. Diagnostic biomarker

A diagnostic biomarker is an indicator that helps diagnose, detect, or confirm the presence of a specific disease or condition or distinguishes between different subtypes of a disease, allowing for precise identification and classification of affected individuals.[12] These biomarkers can not only diagnose diseases but also revolutionize how to classify them. For instance, cancer diagnosis is shifting from a traditionally organ-based approach to a more modern molecular and imaging-based classification system, enabling a more precise and personalized understanding of the disease.[13]

3.1.2. Monitoring biomarkers

A biomarker that can be repeatedly measured to track the progression of a disease or medical condition, detect exposure to a therapeutic or environmental agent, or monitor the effectiveness of a treatment is considered a monitoring biomarker.[12] These biomarkers can be detected in various bodily samples, including blood, urine, and tissue specimens. By measuring the levels of these biomarkers, doctors can achieve a better understanding of disease progression or treatment effectiveness. Some examples of monitoring biomarkers include cancer antigen 125 for ovarian cancer, prostate-specific antigen for prostate cancer, and viral load for human immunodeficiency virus (HIV) infection.[12]

3.1.3. Pharmacodynamics biomarkers

Pharmacodynamic biomarkers play a role in assessing the efficacy and pharmacological impact of a drug, enabling healthcare professionals to determine whether treatment has the desired effect. An example is *PI3K* inhibitors, which are used to treat various cancers. The *PI3K* signaling pathway includes multiple downstream targets, including *AKT*. On activation of the *PI3K* pathway, *AKT* becomes phosphorylated. Therefore, phosphorylated *AKT* (pAKT) can serve as a pharmacodynamic biomarker to confirm that *PI3K* inhibitor treatment is effectively inhibiting the *PI3K* pathway. A decrease in *pAKT* levels indicates that the inhibitor is working.[14]

3.1.4. Predictive biomarkers

A predictive biomarker indicates the probability of an individual or group experiencing a beneficial or harmful effect from a medical intervention or environmental agent, enabling healthcare professionals to predict treatment outcomes and make informed decisions.[15] An excellent example of a predictive biomarker is the human epidermal growth factor receptor 2 (*HER2*) biomarker for breast cancer. Women with breast cancer who test positive for *HER2* have a better chance of responding to treatment with targeted drugs, such as trastuzumab (Herceptin). In this case, the *HER2* biomarker predicts the likelihood of response to a specific treatment. Other examples of predictive biomarkers include the *KRAS* biomarker for colon cancer and the *BRCA* biomarker for breast and ovarian cancers.[15]

3.1.5. Prognostic biomarkers

Prognostic biomarkers are indicators that predict the potential course and outcome of a disease if left untreated, providing valuable insights into the likely progression and severity of the condition. Prognostic biomarkers, such as low-density lipoprotein (LDL) cholesterol, predict the likely outcome of a disease if left untreated. Elevated LDL cholesterol levels indicate a higher risk of developing atherosclerosis and experiencing severe events, such as heart attack, stroke, or death, in individuals already diagnosed with the disease.[13]

3.1.6. Imaging biomarkers

Imaging biomarkers can be used to detect diseases, track disease progression, and evaluate treatment effectiveness. There are two main types of imaging biomarkers. Structural imaging biomarkers indicate changes in the body structure,

such as tumor size or the number of lesions. Examples include magnetic resonance imaging (MRI), computed tomography (CT), and positron emission tomography (PET) scans. Functional imaging biomarkers indicate changes in function or metabolism, such as blood flow or oxygen use. Examples include functional MRI, single-photon emission CT, and PET.[16]

3.1.7. Molecular biomarkers

Molecular biomarkers can detect molecular changes or specific molecules. There are two main types. Biochemical biomarkers detect changes in specific chemicals in the body. Examples include blood glucose, cholesterol, and creatinine levels. Molecular profile biomarkers detect changes in the DNA, RNA, or proteins of a cell or tissue. Examples include gene expression, microRNA, and proteomic profiles. Molecular biomarkers are useful for diagnosing diseases, predicting prognosis, and monitoring treatment response.[17]

3.2. Current scenario of biomarkers in diagnosis and personalized medicine

Biomarkers play a crucial role in predicting prognosis, choosing suitable treatments, and tracking therapeutic responses.[17,18] They facilitate early disease detection, patient stratification based on disease risk or treatment response, and personalized treatment decision-making.[17,19] Biomarkers are essential for diagnosing and tailoring treatment for various diseases, such as breast cancer and sarcoidosis. They help identify conditions early, predict prognosis, anticipate treatment response, and guide therapy, ultimately enhancing patient outcomes.[9,20] Similarly, novel biomarkers discovered through gene expression profiling and omics sciences offer the potential for improving diagnosis and predicting disease progression in sarcoidosis, underscoring the need for better diagnostic tools in this area.[21] Breast cancer subtypes are classified and targeted therapies (e.g., tamoxifen and trastuzumab) are guided using biomarkers such as the estrogen receptor, progesterone receptor, and *HER2*. Treatment selection with *BRAF* inhibitors in patients with melanoma is guided by biomarkers such as *BRAF* mutations.[22,23] Diagnostic biomarkers also play a crucial role in autoimmune diseases such as rheumatoid arthritis, lupus, and multiple sclerosis for confirming diagnoses and tracking disease activity. In addition, biomarkers for disease severity are used to help tailor treatment for inflammatory skin conditions such as atopic dermatitis and psoriasis.[24]

3.3. Application of biomarkers and their advantages and disadvantages

Biomarkers have demonstrated several advantages; early disease detection can be achieved using biomarkers to identify molecular signatures or abnormalities associated with a condition. Matching patients to the most effective treatments based on their characteristics through biomarker-guided therapy can optimize treatment efficacy and minimize adverse effects.[17,25,26] The evaluation of disease risk, along with diagnosis, prognosis, and treatment, can be supported by using biomarkers as early warning systems.[17,27] They can reduce bias and misclassification in epidemiological research by increasing the sensitivity and specificity of measuring exposures or risk variables. They can help identify patients prone to illness and provide more effective population stratification based on illness risk. They can provide insights into the disease course, prognosis, and treatment effectiveness.[27] Despite their advantages, biomarkers have limitations. One notable disadvantage is the risk of overuse or misuse, which can lead to misinterpretation of results due to a lack of comprehension of the disease's pathophysiology and intervention mechanisms.[28] Furthermore, the diagnostic processes for certain diseases, such as cardiovascular diseases (CVDs), may require a multimarker approach that utilizes various biomarkers. This could potentially increase the cost and complexity of the diagnostic procedures.[26] In addition, regulatory restrictions on the approval and validation of biomarker data create added challenges in the drug development process.[26] These constraints underscore the importance of an equitable and informed strategy for utilizing biomarkers in the healthcare industry.[29]

3.4. Common types of biomarkers

Biomarkers are essential in clinical diagnostics and biomedical research, and they are derived from different biological materials. Immunohistochemistry assays are often used to detect protein biomarkers.[30] Biomarkers in RNA, especially chimeric RNA present in exosomes obtained from bodily fluids, are used to diagnose diseases.[31] Exosomes, which are tiny extracellular vesicles found in bodily fluids, contain abundant tumor-specific material such as nucleic acids and proteins, making them highly useful for cancer diagnostics.[32] Biomarkers can be detected in blood, saliva, urine, peritoneal fluid, and other biofluids, providing a non-invasive method for detecting and monitoring diseases.[33]

4. Discussion

4.1. History of biomarkers

The term "biomarker" dates back to the 1800s.[34] Biomarkers were referred to as surrogate markers in the late 1980s and later became known as surrogate endpoints.[34] The concept began with the discovery of certain molecules or cells in the body that could be used to check biological body processes, diagnose certain diseases, or evaluate pharmacological

responses to therapeutic interventions.[35] The discovery of immunoglobulin-free light chains in 75% of patients with myeloma in a groundbreaking 1848 study marked the detection of the first known biomarker. This breakthrough paved the way for the discovery of numerous biomarkers across a wide range of diseases.[35] Dr. Henry Bence-Jones identified the immunoglobulin-free light chain in 1847, and his research published the following year shed light on this crucial biomarker.[35]

The definition of biomarkers has undergone significant revisions over the past 50 years, adapting to new scientific discoveries and clinical breakthroughs that have enhanced our understanding of their role in healthcare.[35] In 1973, Rho *et al*. used the term "biomarkers" for the 1st time and defined it as the presence or absence of a specific biological material in the body.[36] In the 20th century, scientists began using blood tests to detect substances such as cholesterol and creatinine, which were among the earliest biomarkers used to understand and diagnose conditions related to heart and kidney functions.[36] The advent of molecular profiling techniques in the 21st century has enabled the development of more precise and personalized biomarkers, facilitating advances in personalized medicine and targeted therapies.[36] Today, biomarkers are utilized in a wide range of fields, from medicine to environmental monitoring, illustrating their broad applicability and importance in various scientific disciplines.[36]

4.2. Types and characteristics of biomarkers

There are several ways to categorize biomarkers based on their functions.[12]

- Imaging biomarkers:

Imaging biomarkers are used to visualize and measure biological processes in the body. MRI, CT, and PET scans are non-invasive techniques that enable the observation of disease progression and response to therapy.[36]

- Molecular biomarkers:

Molecular biomarkers include genes, proteins, and other molecules that provide insights into the disease state or treatment effects. They can be detected through blood tests, biopsies, or other samples and are crucial for understanding the underlying mechanisms of diseases.[36]

- Diagnostic biomarkers:

Diagnostic biomarkers are used to identify the presence of a disease or condition and can aid in their early detection, allowing for timely intervention and treatment.[36]

- Predictive biomarkers:

Predictive biomarkers provide information on the likely response of patients to a particular treatment. They are essential in personalized medicine, helping tailor treatments to individual patients based on their predicted response.[36]

- Prognostic biomarkers:

Prognostic biomarkers provide insights into the likely course or outcome of a disease. They can aid in understanding disease progression and in guiding decisions regarding the necessary aggressiveness of treatment.[36]

4.3. Applications and importance of biomarkers

Biomarkers play pivotal roles in numerous aspects of medical research and healthcare.[12]

- Drug development:

In drug development, biomarkers are used to assess the efficacy and safety of new drugs. They assist in identifying potential targets for therapeutic intervention and in monitoring treatment effects.[36]

- Disease monitoring:

Biomarkers are used to monitor disease progression and treatment response. They provide valuable information that can guide adjustments in therapy to improve patient outcomes.[36]

- Personalized medicine:

Biomarkers in personalized medicine enable customized treatment plans based on the individual characteristics of the patient. This approach can lead to more effective and targeted therapies, minimizing side effects and improving overall health outcomes.[36]

- Environmental monitoring:

Beyond healthcare, biomarkers are also used in environmental monitoring to assess the impact of pollutants and other environmental factors on human health and ecosystems.[36]

The ongoing research and development in the field of biomarkers continue to expand their applications and improve their accuracy, making them indispensable tools in modern science and medicine.[36]

4.4. Biomarkers in African diseases

Throughout history, biomarkers have become increasingly precise and reliable, allowing for more specific and personalized approaches to medicine.[37] An ideal biomarker must meet certain criteria, including accessibility, specificity, and sensitivity to the investigated pathology and the ability to be translated from research to clinical practice.[37] In sub-Saharan Africa, the leading causes of illness and death include infectious diseases such as malaria, tuberculosis (TB), and HIV infection as well as non-infectious diseases such as diabetes and CVDs, which together account for the majority of the region's disease burden.[38] Early detection of specific biomarkers for *Plasmodium* infection is vital in

malaria management, as it allows for prompt and informed decision-making, enabling healthcare professionals to initiate effective treatment plans and improve patient outcomes.[39] Such biomarker-based detection methods, combined with appropriate treatment approaches, can considerably help reduce human reservoirs of the parasite, which frequently contribute to the persistence of malaria infection transmission in endemic zones of Africa where asymptomatic malaria is widespread.[39] Some examples of malaria biomarkers are *Plasmodium falciparum* lactate dehydrogenase, histidine-rich proteins (HRPs), and hemozoins.[39] Biomarkers may also be used to distinguish latent TB infection and predict the likelihood of relapse, treatment response, and the development of clinical disease. These insights are urgently needed to establish precise endpoints for clinical trials of new drugs and vaccines.[40] In addition, several biomarkers are now the main focus of efforts to enhance techniques for assessing the risk of CVDs.[41] The use of these biomarkers is appealing because they combine signals from several pathophysiological pathways and offer combined predictive utility.[41] Elevated concentrations of fibrinogen, interleukin-6, CRP, and galectin-3 are known risk factors for CVDs and may serve as biomarkers to partially anticipate the onset of the condition.[41]

4.5. Disease-related biomarkers

Bravo *et al*. reported the discovery of 131,012 disease–biomarker correlations involving 2,803 genes and 2,751 disorders through text mining.[42] Biomarkers associated with neoplasms are crucial for identifying, diagnosing, and managing cancer. This group includes a wide range of disorders involving the nervous system, spine, and brain. Biomarker research in neurological diseases aims to identify markers that can assist in the diagnosis and treatment of neurological disorders.[42] CRC biomarkers, such as *RAS*, microsatellite instability, *HER2*, consensus molecular subtypes, and Circulating tumor DNA/Circulating tumor cells, facilitate targeted therapy and adjuvant chemotherapy by allowing for patient stratification and identifying those who can benefit from adjuvant treatment.[43] In atopic dermatitis, biomarkers are particularly important for selecting appropriate treatments for patients. They assist in prognosis, measuring the treatment response, and assessing disease severity.[44] In rheumatoid arthritis, biomarkers, including autoantibodies and disease-modifying antirheumatic drug pharmacogenetics, are used to identify predictors of treatment response and personalized therapy.[45] The availability of real-world genomic data and advancements in technology have facilitated biomarker-driven drug development, shifting the focus from a "one-drug-fits-all" approach to a more tailored strategy. This has led to the creation of targeted therapeutics and creative clinical trial designs.[46]

4.6. Drug-related biomarkers

In neurodegenerative disorders such as Alzheimer's disease, accurate biomarkers are essential for adaptation to therapy and timely diagnosis.[22] The event-related potential biomarker (ERP), particularly the P300 technique, has shown promise as a surrogate for predicting the cognitive potential of medicinal products in neurocognitive diseases, including Alzheimer's disease.[22] The ERP P300 latency has been established as a measurable, objective parameter for monitoring the progression of cerebral decline and response to therapy in individuals with Alzheimer's disease dementia as well as for identifying changes in brain function. P300 tests are an excellent tool for the early development of pre-cognitive drugs, as they enable direct monitoring of the functioning of large neural networks in response to auditory stimulation.[22] Other neurological and psychiatric conditions, such as multiple sclerosis, epilepsy, Huntington's disease, transient ischemic stroke, intellectual disability, attention-deficit hyperactivity disorder, traumatic brain injury, and mental health issues, have also been researched regarding ERP P300 latency.[22] Serum levels of the enzyme diamine oxidase serve as a diagnostic marker for respiratory allergies. In addition, protein deamination and extracellular vesicles have been identified as novel biomarkers for the early pre-motor stages of Parkinson's disease.[23] DNases have been identified for their role in cleaving extracellular DNA and are considered a potential marker for systemic lupus erythematosus.[47] Table 1 shows an overview of disease- and drug-associated biomarkers with implications for personalized medicine.

4.7. Importance of biomarkers drug development and disease management in Africa

The health of individuals in third-world countries is persistently under threat, accounting for approximately 90% of the global health burden, whereas only 10% of worldwide research is focused on developing effective solutions to alleviate this burden.[48] Biomarkers may include measurements taken directly from biological samples, such as amniotic fluid, cerebrospinal fluid, plasma, whole blood, peritoneal fluid, pleural fluid, saliva, serum, seminal fluid, sweat, and urine.[49] In addition, they may include measurements such as brain imaging, which do not require direct sampling of biological materials but assess modifications in the nervous system's composition or function.[49] Cholesterol levels serve as a biomarker and risk indicator for coronary and vascular diseases.[49] A doctor can assess a patient's cholesterol levels to predict the likelihood of a heart attack. If anticholesterol medications are prescribed,

Table 1. Overview of disease- and drug-associated biomarkers with implications for personalized medicine

Biomarker type	Associated conditions	Key biomarkers	Purpose/use in therapy	Implications in personalized medicine	References
Disease-related	Neoplasms	Various genes	Diagnosis and management	Enables targeted therapy and patient stratification	42
Disease-related	Neurological disorders	-----	Aid in diagnosis and treatment	Provide treatment for neurological conditions	42
Disease-related	CRC	RAS, HER2	Targeted therapy and chemotherapy	Stratifying patients for adjuvant treatment	43
Disease-related	AD	AD biomarkers	Treatment selection	Predicting prognosis and assessing severity	44
Disease-related	RA	Autoantibodies, DMARD pharmacogenetics	Personalized therapy	Identifying treatment responders	45
Drug-related	AD	ERP P300	Therapy adaptation and diagnosis	Monitoring brain function and therapy response	47
Drug-related	Neurological/Psychiatric conditions	ERP P300, DAO, EVs, DNases	Diagnostic and monitoring	Early drug development and personalized intervention	47,48

Abbreviations: AD: Alzheimer's disease; CRC: Colorectal cancer; DMARD: Disease-modifying antirheumatic drug; ERP P300: Event-related potential P300; EVs: Extracellular vesicles; HER2: Human epidermal growth factor receptor 2; RA: Rheumatoid arthritis; RAS: Rat sarcoma; DAO: Diamine oxidase.

cholesterol levels can be measured at a subsequent appointment to evaluate the medication's effectiveness – specifically, whether it has lowered cholesterol levels and decreased the likelihood of a heart attack.[49]

Patients with diabetes can measure their glucose levels using a single test called hemoglobin A1C, which estimates glucose levels over the previous 2 weeks.[49] Globally, N-terminal pro-B-type natriuretic peptide (NT-proBNP) and high-sensitivity cardiac troponin are widely recognized as the most reliable and authoritative biomarkers for diagnosing heart failure (HF), maintaining their status as the gold standard in diagnostic testing.[50] Although researchers have investigated various new biomarkers to complement established HF biomarkers for risk assessment, prognosis, and treatment monitoring, evidence supporting their practical usefulness is scarce.

Furthermore, most of these novel biomarkers are not specific to the heart, which limits their potential for clinical application.[50] According to a study conducted in Africa, BNP, NT-proBNP, galectin-3, and soluble ST2 have demonstrated diagnostic and prognostic utility in HF.[50] Guidelines for HF management consistently advocate for the utilization of natriuretic peptides and cardiac troponins.[50] The co-epidemic of HIV infection and TB in sub-Saharan Africa presents a significant health challenge, exacerbated by the geographical overlap of the two epidemics and the 18-fold increased risk of TB in individuals co-infected with HIV.[51] Therefore, there is an immediate need to determine prognostic markers for TB in HIV-co-infected patients to advance patient management and accelerate the development of new treatments.[51] A study conducted in South Africa found that elevated levels of lipopolysaccharide-binding protein and soluble intercellular adhesion molecule serve as biomarkers for the risk of TB recurrence in patients co-infected with HIV.[51] Biomarkers are crucial for successful drug development.[33] Unfortunately, in Alzheimer's disease, only a few biomarkers are available due to the involvement of multiple processes. There are a limited number of target engagement biomarkers that can provide early indications of pharmacological proof, and no surrogate markers exist that can predict clinical outcomes. Furthermore, no validated outcome biomarkers have been identified that correlate with clinical outcomes in trials designed for disease modification. These limitations present challenges for drug development in Alzheimer's disease, resulting in higher failure rates, particularly for disease-modifying treatments.[52] Researchers have identified plasma LDH, HRP II, aldolase, and hemozoin formation as key biomarkers with significant potential for drug targeting and malaria detection, paving the way for breakthroughs in diagnosis and treatment.[53] In African children, it is difficult to differentiate severe falciparum malaria from other severe febrile illnesses that also involve *P. falciparum* infection.

However, measuring plasma HRP II levels can help predict the likelihood of severe malaria and distinguish it from other severe illnesses in children with parasitemia. This highlights the potential value of developing plasma HRP II concentration as a diagnostic tool for severe falciparum malaria in African children.[53] This justifies the use of plasma

HRP II concentration as a biomarker for assessing severe falciparum malaria in this population.[53] Several deaths from communicable and non-communicable diseases occur in low- and middle-income countries due to a lack of early diagnosis and treatment.[48] Biomarkers can help by serving as indicators of disease conditions or treatment responses. However, results from developed countries may not be directly applicable to developing countries owing to differences in disease patterns.[48] Biomarker candidates identified through advanced technology hold potential; however, their application is hindered by challenges such as disease heterogeneity and pre-analytical variability.[48] Economic constraints, a lack of education and awareness, and various social and ethical issues also hinder biomarker discovery in developing countries.[48] Africa lacks the essential resources and infrastructure for young researchers to engage in cutting-edge clinical trials.[48] A recent survey in Nigeria showed that traditional health professional training is widely accepted for interdisciplinary research; however, the necessary scientific skills are lacking.[48] Respondents identified gaps in post-doctoral training, clinical trial competency, and bioinformatics. Although efforts are being made to include African genetic diversity in global genomic data, a lack of skilled personnel hinders the storage, retrieval, analysis, and interpretation of clinical, epidemiological, and genomic data.[48] Biomarkers are essential for developing targeted therapies and personalized treatment plans, particularly in Africa, where healthcare disparities and disease burdens present unique challenges. By identifying biomarkers specific to the African population or reflecting regional variations in disease pathology, researchers and healthcare professionals can tailor interventions and accelerate the approval process for novel therapeutics. This is particularly important in the African context, where efficient drug development processes are crucial for delivering innovative treatments to those in needs. Figure 1 shows the importance of drug development and disease management.

4.8. Current status, challenges, and future perspectives

To support the next generation of diagnostic platforms, biomarkers are urgently needed.[54] Although there are challenges in using biomarkers as diagnostic or prognostic

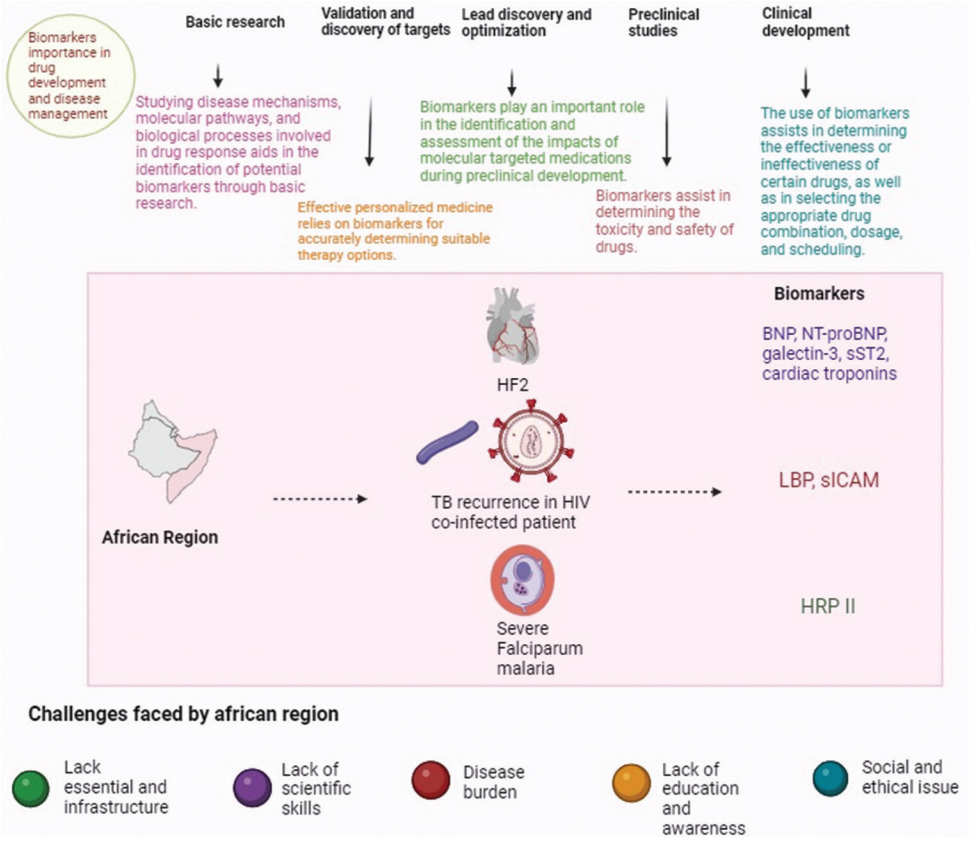


Figure 1. Importance of biomarkers in drug development and disease management
Abbreviations: BNP: B-type natriuretic peptide; HF2: Heart failure 2; HIV: Human immunodeficiency virus; HRP II: Histidine-rich protein II; LBP: Lipopolysaccharide-binding protein; NT-proBNP: N-terminal pro B-type natriuretic peptide; sICAM: Soluble intercellular adhesion molecule; sST2: Soluble ST2; TB: Tuberculosis.

markers, their application may mitigate the drawbacks of existing tests and improve patient outcomes through robust analytical and validation techniques.[54] Advancing research involves integrating favorable biomarkers—both molecular and image-based—and leveraging artificial intelligence to optimize their combinations.[55] Directly comparing these biomarkers in clinical settings would enhance our understanding of their effectiveness.[55] By leveraging the vast data generated through ongoing screening efforts, advanced mathematical and computational models powered by ML can extract valuable insights.[55] However, this requires a systematic collection of patient samples within screening contexts.[55] Moreover, challenges such as demonstrating cost-effectiveness and navigating regulatory approval processes must be addressed.[55] Despite initial logistical and financial hurdles, these efforts will ultimately yield significant efficiency gains.[55] Although such an endeavor may seem daunting initially, the long-term outcomes could prove highly beneficial.[55] This review provides a compelling perspective on the use of biomarkers in drug and disease development in Africa, an area with limited resources. The significance of this topic in such regions cannot be underestimated, particularly given the need to shift focus toward the utilization of biomarkers in drug and disease development. To tackle these challenges, our study has made this issue a central focus. Thus, the potential of biomarkers in drug and disease development in Africa should be investigated through original research studies. In the next 5 years, we anticipate substantial advancements in disease treatment through the creation of groundbreaking medications, facilitated by the utilization of biomarkers.

5. Limitations

This review has some limitations. First, there is a lack of literature on the use of biomarkers in drug and disease development in Africa, resulting in a scarcity of recent references to include. In addition, we have only mentioned specific biomarkers used in Africa due to the absence of original studies on the subject.

While examining the significance of biomarkers in disease and drug development in Africa, it is important to recognize certain limitations. First, the availability of reliable data is restricted due to inadequate representation in global research, potentially resulting in gaps in the analysis. Furthermore, the differing healthcare infrastructures across African nations can impact the relevance and generalizability of findings related to biomarkers. In addition, there is a dependence on studies employing varied methodologies, which could lead to inconsistent conclusions. Finally, the rapid advancement of the field means that this review may not comprehensively capture all recent developments.

6. Conclusion

The African disease landscape and drug development are both critically important, requiring specific biomarkers for effective detection. It would be beneficial to prioritize increased awareness, campaigns, and research opportunities aimed at discovering, utilizing, and implementing more biomarkers to address prevalent diseases in Africa and enhance drug development. Such efforts would not only improve healthcare but also help preserve the African heritage.

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The authors declare they have no competing interests.

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