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REVIEW

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Harnessing artificial intelligence (AI) for early detection of atherosclerotic cardiovascular disease (ASCVD) in sub-Saharan Africa

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ABSTRACT

Cardiovascular diseases (CVDs), particularly atherosclerotic cardiovascular disease (ASCVD), are the leading causes of mortality worldwide, with sub-Saharan Africa facing significant challenges in their early detection and management. Traditional risk assessment tools, such as the Framingham score and ASCVD Estimator Plus, are poorly suited to the unique genetic, environmental, and lifestyle factors present in the region's populations. These tools often fail to provide accurate risk predictions, underscoring the urgent need for more advanced and adaptable solutions. This article explores the transformative potential of AI, specifically machine learning (ML) and deep learning (DL), in improving ASCVD risk prediction and early detection in sub-Saharan Africa. AI models, such as Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks, can process vast amounts of data, including medical imaging, genetic profiles, and lifestyle inputs, offering more precise and personalized risk assessments. A key innovation discussed in this paper is the Jos CVD Risk App, developed specifically for use in sub-Saharan Africa. This AI-driven tool leverages non-invasive anthropometric measurements to assess ASCVD risk, offering a more accessible and affordable alternative to traditional methods. By addressing the limitations of conventional tools, this app provides scalable, accurate, and cost-effective solutions for CVD risk assessment in underserved regions. The article highlights the need for continued innovation, data collection, and refinement of AI models to enhance their predictive accuracy and contribute to better cardiovascular outcomes in sub-Saharan Africa, ultimately improving public health across the region.

KEYWORDS

Atherosclerotic cardiovascular disease; Artificial intelligence; Machine learning; Deep learning

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Introduction

CVDs continue to be the world's leading cause of death, claiming nearly 17.9 million lives each year [1]. A key player in this health crisis is atherosclerosis, a condition where plaques progressively build up in arterial walls. Often, this silent threat goes unnoticed for years, only revealing itself through catastrophic events like heart attacks and strokes [2]. Detecting the early stages of atherosclerosis, known as subclinical atherosclerosis (SA), is therefore critical for preventing and managing CVDs effectively [3].

During its symptom-free phase, advanced imaging techniques like CT scans and Carotid Ultrasound are pivotal in redefining traditional risk scores, which frequently underestimate the midterm and lifetime cardiovascular risk in asymptomatic individuals [4]. Traditional risk assessments, such as the 10-year Framingham risk score and the American College of Cardiology's ASCVD Estimator plus, are widely used to guide clinical decisions. However, these models often fall short in accounting for the complex interplay of genetic, lifestyle, and environmental factors influencing CVD risk, particularly in sub-Saharan African populations [5]. Designed primarily for Caucasian and select Western ethnic groups, these calculators also necessitate phlebotomy and biochemical data, which many individuals may decline to provide during epidemiological studies in sub-Saharan Africa.

Moreover, the ASCVD Estimator plus is limited to individuals aged 40-79 years, excluding many adults from comprehensive screenings. Our previous research indicates that the risk threshold for subclinical atherosclerosis in sub-Saharan African adults is around 39.5 years [6]. As a result, individuals close to this age who may be at intermediate risk cannot be adequately screened using this model. These limitations highlight the challenges in obtaining accurate, large-scale data for population-based CVD risk assessments with these two models.

Carotid ultrasound, despite being the gold standard for measuring Carotid Intima-Media Thickness (C-IMT) and confirming subclinical atherosclerosis, poses significant logistical challenges for large-scale population studies. The procedure is cumbersome, expensive, and time-consuming, requiring skilled healthcare personnel and reliable transportation and power supplies-resources often scarce in sub-Saharan Africa. This article explores the transformative potential of AI, specifically ML and DL, in improving ASCVD risk prediction and early detection in sub-Saharan Africa.
Machine Learning and Deep Learning in Cardiovascular Risk Prediction

Machine learning encompasses a variety of algorithms that enable computers to learn patterns from data without being

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explicitly programmed. In the context of ASCVD, ML models such as decision trees, support vector machines, and ensemble methods (like random forests and gradient boosting) have demonstrated superior performance in risk prediction compared to traditional methods [7]. These models can handle high-dimensional data, making them particularly adept at identifying subtle patterns and interactions between risk factors that conventional models might miss.

Deep learning, a subset of machine learning, uses neural networks with many layers (hence "deep") to model complex relationships in data. These networks are capable of learning from unstructured data such as images, texts, and time series, making them particularly suited for applications in medical imaging, natural language processing, and predictive analytics [8]. CNNs, for example, are particularly effective in analyzing imaging data, such as coronary CT scans and carotid ultrasound images, to detect subclinical atherosclerosis. Recurrent neural networks (RNNs) and their variants, like LSTM networks, are useful for analyzing time-series data, which is critical in monitoring changes in cardiovascular risk factors over time [9].

Deep Learning in Cardiovascular Risk Assessment

Medical imaging

CNNs have revolutionized the analysis of medical images. In cardiovascular risk assessment, CNNs can analyze coronary CT angiography, echocardiograms, and carotid ultrasound images to detect signs of atherosclerosis, calcifications, and other cardiovascular anomalies with high accuracy. For instance, CNNs have been used to identify plaque characteristics and stenosis in coronary arteries, providing critical insights into an individual's cardiovascular risk [10].

Electrocardiogram (ECG) analysis

Deep learning models can analyze ECG signals to detect arrhythmias, ischemic changes, and other abnormalities indicative of underlying cardiovascular issues. Hannun et al. demonstrated that a deep neural network could classify a range of arrhythmias with performance comparable to board-certified cardiologists [11]. Such models can continuously monitor ECG data, offering real-time risk assessment and early warnings.

Predictive analytics

Deep learning models can integrate diverse data sources—genetic information, electronic health records (EHRs), lifestyle factors, and demographic data—to create comprehensive risk profiles. These models excel at identifying complex interactions among risk factors that traditional models might overlook. For example, a deep learning model trained on EHR data significantly outperformed traditional risk calculators in predicting 5-year mortality in patients with suspected coronary artery disease [12].

Time-series analysis

LSTM networks are particularly effective in analyzing time-series data, making them ideal for tracking changes in cardiovascular risk factors over time. These models can predict future cardiovascular events by analyzing trends and patterns in patients' medical histories, laboratory results, and biometric data [7].

Advantages of ML and Deep Learning in ASCVD Risk Assessment

Precision and personalization

ML and deep learning models can offer personalized risk assessments by considering a wide array of factors unique to each individual. This leads to more accurate predictions compared to one-size-fits-all approaches of traditional risk calculators [7].

Early detection

These models excel in early detection of SA by identifying complex patterns that might indicate the onset of atherosclerosis long before clinical symptoms appear [13].

Scalability

Once trained, ML models can quickly process large datasets, making them suitable for large-scale population screening and continuous monitoring. This scalability is particularly advantageous in settings with limited healthcare resources [14].

Challenges and Future Directions

Despite its promise, the implementation of deep learning in cardiovascular risk assessment faces several challenges:

Data quality and quantity

Deep learning models require large, high-quality datasets to train effectively. Inconsistent or incomplete data can impair model performance [15].

Interpretability

Deep learning models are often criticized as "black boxes" because their decision-making processes are not easily interpretable. Developing methods to explain these models' predictions is crucial for clinical acceptance [16].

Integration with clinical practice

Integrating deep learning models into clinical workflows requires careful consideration of regulatory, ethical, and operational factors. Ensuring these models complement rather than complicate clinical decision-making is essential [17].

Jos Cardiovascular Disease Risk App

To address the shortcomings of the Framingham risk score and the ASCVD Estimator plus models, a groundbreaking solution tailored for sub-Saharan African populations has emerged: the Jos CVD Risk App. This innovative tool, designed for smartphones, offers a more accurate and reliable method for assessing cardiovascular risk in this region [6]. Unlike traditional models that rely on invasive procedures, the Jos CVD Risk App employs a non-invasive approach, replacing biochemical tests with two novel obesity anthropometric indices: abdominal height and body surface index [18,19]. By incorporating these 10 risk factors, the app provides a comprehensive evaluation without the need for phlebotomy, making it a user-friendly option for widespread use.

The Jos CVD Risk App sets a new standard in cardiovascular risk assessment for sub-Saharan Africa, thanks to its robust foundation built on precise scientific data. The app's cut-off risk values for its various traditional risk factors were meticulously determined using Receiver Operating

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Characteristic (ROC) curves, derived from ultrasound measurements of carotid intima-media thickness in 221 adult Nigerians. With a risk threshold of C-IMT set at 0.78 mm for subclinical atherosclerosis, this approach ensures unparalleled accuracy and reliability [20]. This scientifically grounded methodology not only enhances the app's precision but also underscores its suitability for the unique health profiles found in sub-Saharan Africa. The Jos CVD Risk App is more than just a tool-it's a revolutionary step towards better heart health in the region, providing actionable insights and empowering individuals with the knowledge they need to take control of their cardiovascular well-being. In the thrilling arena of cardiovascular risk assessment, our groundbreaking Jos CVD Risk app has entered the ring, ready to spar with the heavyweight champion: the ASCVD Estimator Plus app of the American College of Cardiology. As the dust settles and the numbers crunch, the results are nothing short of spectacular.

In a showdown of statistical prowess, both contenders displayed a formidable positive correlation, boasting an impressive R-value of 0.805. With a resounding p-value of 0.000, the evidence is clear: equivalence reigns supreme [20]. But the real knockout blow comes in the form of accessibility and efficiency. Our innovative approach relies solely on anthropometric and historical indices, stripping away unnecessary complexities. This not only makes it a cost-effective solution but also a logistical marvel, particularly for large-scale epidemiological studies. In the grand arena of preventive cardiology, where every move counts, our method emerges as the undisputed champion. With its simplicity, affordability, and unwavering accuracy, the Jos CVD Risk App is poised to revolutionize cardiovascular risk assessment in sub-Saharan Africa, paving the way for more effective prevention and management of heart disease in this underserved region

Discussion

The effectiveness of machine and deep learning models depends heavily on the quality and quantity of data available. In sub-Saharan Africa, data collection can be challenging due to limited healthcare infrastructure and resources. However, the Jos CVD Risk Calculator offers a practical solution by facilitating the collection of extensive and accurate data across diverse populations. This can provide the foundational dataset required for developing robust ML-based risk models tailored to sub-Saharan African populations.

Moreover, ongoing advancements in AI technology are making it easier to deploy these sophisticated models in resource-constrained settings. Cloud computing, for example, allows complex computations to be performed remotely, reducing the need for expensive local infrastructure [21]. Additionally, mobile health technologies can enable widespread data collection and real-time risk assessment, even in remote areas. The early detection of subclinical atherosclerosis is vital for improving cardiovascular health outcomes. While traditional risk calculators and imaging techniques have their limitations, innovative tools like the Jos CVD Risk Calculator and advancements in ML and deep learning offer new avenues for precise and non-invasive risk assessment. By leveraging these technologies, we can significantly enhance cardiovascular prevention strategies and health outcomes in sub-Saharan Africa. Through continued innovation and the integration of AI-driven approaches, we move closer to a future where cardiovascular diseases can be predicted and prevented with unprecedented accuracy.

Conclusions

The incorporation of AI into cardiovascular medicine is set to transform healthcare delivery in sub-Saharan Africa. By utilizing AI-driven solutions designed to address local issues, we can overcome the typical barriers to cardiovascular care and build sustainable healthcare systems. Going forward, it is crucial to invest strategically in digital infrastructure, enhance skills, and promote interdisciplinary collaboration. As these technologies evolve, their implementation in clinical practice is expected to facilitate more proactive and accurate cardiovascular care. This shift in healthcare delivery has the potential to significantly enhance health outcomes across the region, particularly in underserved areas where conventional diagnostic tools are often lacking.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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