

EXAMINING THE COST BENEFIT ANALYSIS FOR TRADITIONAL AND TECHNOLOGICAL APPROACHES TO CARDIOVASCULAR SCREENING IN RWANDAN HEALTHCARE: A MIXED-METHODS STUDY WITH A FOCUS ON LIFESTEN HEALTH

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Abstract: - Cardiovascular diseases (CVDs) pose a significant global health challenge, contributing to millions of deaths and disability-adjusted life years (DALYs) annually. This paper examines the efficacy and cost-effectiveness of government-led cardiovascular health screening approach and technology based transdermal optical imaging screening via Lifesten Health in Rwanda.

Using a mixed-methods approach, this study combines systematic literature review and narrative synthesis with qualitative cost analysis derived from review and interview data. Drawing inspiration from a previous study by Asmah et al. (2020), questions were tailored to explore the cost-benefit ratio of traditional cardiovascular health screening approaches and Lifesten's tech enabled cardiovascular care methods. Expert opinions were sought from professionals affiliated with the NCD clinics of the Rwandan Ministry of Health and Lifesten. Thematic analysis of expert responses revealed recurring themes.

Government-led screening in Rwanda typically relies on sphygmomanometers, whereas technological approaches involve wearable devices and smartphone applications. While both methods demonstrate effectiveness, technological solutions offer greater efficiency due to their minimal equipment and training requirements. However, challenges such as digital illiteracy impeding technological adoption and shortages of materials and healthcare providers for conventional screening, persist.

Investing in digital literacy is paramount for the successful implementation of digital cardiovascular disease screening, given its efficiency and low training demands. Concurrently, enhancing healthcare provider training and ensuring adequate equipment for conventional screening are essential for improving its effectiveness. A dual-focused approach holds promise for significantly reducing the burden of mortality and morbidity associated with cardiovascular diseases in Rwanda.

Keywords: Diagnostics, health tech, health promotion, transdermal optical imaging, blood pressure.

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INTRODUCTION

Cardiovascular disease burden: global to regional to local perspective

One major type of non-communicable diseases (NCDs) are cardiovascular diseases (CVDs). These are conditions that affect the heart and blood arteries and are leading cause of death worldwide [1]. Considering disability-adjusted life years (DALYs)

and fatalities, cardiovascular diseases (CVDs) accounted for 393 million DALYs and 17.9 million deaths globally in 2019. By 2030, non-communicable diseases (NCDs) are expected to overtake communicable illnesses as the primary cause of death in low- and middle-income countries (LMICs). CVDs will account for a significant portion of this burden globally [2], [3]. Table 1 shows global burden of cardiovascular diseases in 2021

Table 1: Global burden of cardiovascular diseases in 2021

Age – standardized total cardiovascular disease			All ages total cardiovascular disease					
Rate per 1000			Count			Rate per 1000		
DAYLS	Death	Prevalence	DALYS	Deaths	Prevalence	DAYLS	Death	Prevalence
4,942.3	245.1	7,241.7	422,000,000	20,500,000	621,000,000	5,347.6	258.8	7,852.0

Source: Lindstrom et al., 2022, *Global Burden of Cardiovascular Diseases and Risks Collaboration, 1990-2021*

The number of deaths worldwide from cardiovascular diseases (CVD) is predicted to rise from 19.8 million in 2022 to 22.2 million by 2030. By 2050, 32.3 million deaths worldwide are expected to be attributable to CVDs [4]. Low-income countries (LICs) are expected to see a more significant surge, with a 44% rise in CVD deaths by 2030 and a substantial 190% escalation projected by 2050. These estimates highlight the urgent need for focused treatments and international cooperation in order to reduce the upcoming spike in deaths [4], [5].

In Africa, cardiovascular diseases (CVDs) constitute the predominant share of the noncommunicable disease (NCD) burden, contributing to 38.3% of NCD-related deaths and causing 22.9 million Disability-Adjusted Life Years (DALYs) [6]. Over a million deaths in sub-Saharan Africa have been attributed to cardiovascular disease (CVD) in 2019, accounting for 5.4% of all CVDs deaths worldwide and 13% of all deaths in Africa as a whole [7].

Cardiovascular diseases are one of the main causes of death and disability in Rwanda, presenting a serious health concern. In the country, CVDs caused 4.6% of life years adjusted for disability (DALYs) and 11.92% of deaths in 2019 [8]. Common CVDs in Rwanda include ischemic heart disease, rheumatic heart disease, stroke, and hypertensive heart disease [8]. All of these conditions present unique risks to the cardiovascular health of the populace. Smoking, physical inactivity, poor diet, obesity, diabetes, dyslipidemia, hypertension, and psychosocial stress are all prevalent risk factors for CVDs in Rwanda [9], [10]. Notably, of the approximately one million people with high blood pressure, only 80,000 are enrolled in clinics, indicating potential gaps in healthcare access and management [11].

Table 2: Rwanda burden of cardiovascular diseases in 2021

Age – standardized total cardiovascular disease			All ages total cardiovascular disease					
Rate per 1000			Count			Rate per 1000		
DAYLS	Death	Prevalence	DALYS	Deaths	Prevalence	DAYLS	Death	Prevalence
5,204.8	264.0	7,018.7	343,000	13,300	584,000	2,587.4	99.8	4,388.0

Source: Lindstrom et al., 2022, *Global Burden of Cardiovascular Diseases and Risks Collaboration, 1990-2021*

Additionally, the prevalence of different CVDs varies. For example, 15% of adults in Rwanda suffer from hypertension, a significant risk factor for ischemic heart disease and stroke. But just 3.7% of adults with hypertension are receiving therapy, and only 6.8% are aware that they have the illness [12], [13]. On other hand, rheumatic heart disease is predicted to affect 1.02% of the overall population, but among school-age children, a 2013 study reported a somewhat lower prevalence of 0.68%. Moreover, diabetes affects 5.1% of people, elevated total cholesterol is seen in 2.9% of people, and obesity affects 2.8% of people of both sexes. These figures highlight the complexity of Rwanda’s CVD problem, which calls for all-encompassing approaches to reduce risk factors, improve access to care, and put preventative measures in place for improved cardiovascular health outcomes [11].

Cardiovascular health screening: Traditional vs technological approaches.

The American Heart Association highlights the critical significance of screening for cardiovascular risk factors in persons 18 years of age and older, with a recommended starting age of 20 and a minimum frequency of once every two years [14]. This screening is essential for early detection of potential risk factors, which allows for prompt actions to reduce the risk of cardiovascular diseases. In accordance with the recommendations given by

medical specialists, more frequent tests are recommended for those with certain health issues like diabetes, high blood pressure, chronic kidney disease, and those who have a family history of cardiovascular disorders [15]. This focused approach emphasizes the necessity for proactive and individualized healthcare solutions by acknowledging the higher risk profiles of specific populations.

Periodic screening for cardiovascular risk factors is a preventative technique that makes it possible to identify possible problems early on that could lead to heart-related complications. The overarching objectives is to improve general well-being, lower the prevalence of cardiovascular conditions as well as boost heart health [16].

Cardiovascular disease screening techniques can be divided into two approaches: government-led (traditional) and technological approaches. The government-led cardiovascular screening attempts to identify individuals who, due to a variety of characteristics including age, gender, blood pressure, cholesterol, and others, are at an increased risk of cardiovascular conditions. Then, in an effort to stop or postpone the start of cardiovascular diseases, these individuals are screened and offered therapies including medication, lifestyle counseling, or referrals to specialized care [17]. Besides this, government-sponsored screening programs can be opportunistic, in which screening is provided at regular medical

visits, or population-based, in which screening is extended to all inhabitants of a particular age range or geographic area [18].

Conversely, technology based cardiovascular screening is a new paradigm in the detection or diagnosis of cardiovascular problems, including arrhythmias, heart failure, and coronary artery disease, by means of sophisticated equipment or algorithms [19]. These technologies can be non-wearable, such artificial intelligence-enabled tools that analyze cardiac pictures or electrocardiograms, or wearable, like smartwatches or patches that monitor heart rate and rhythm. Technological screening can be self-initiated, in which patients monitor their heart health using their own devices or apps, or clinician-initiated, in which medical professionals use these tools to improve the efficiency or accuracy of their diagnosis [20].

Basis for comparative analysis

For a variety of reasons, it is extremely important to compare government led screening techniques with technological cardiovascular disease screening techniques. Comparison make it possible to assess the viability, efficacy, and accuracy of different screening instruments in a range of contexts and demographics.

There no comparative studies on this subject because the majority of the research that has been done so far has focused on solitary assessments of the precision, affordability, or usability of certain screening method. This emphasis misses the important detail of making direct comparisons between various approaches or their compliance with accepted practices. This discrepancy may be explained by the different benefits and drawbacks of traditional and technology screening methods, which make their applicability dependent on a number of contextual variables. Closing this gap is essential to improving cardiovascular healthcare practices because comparison will give information on the relative usefulness and suitability of different screening techniques in different healthcare contexts.

This review seeks to provide a comprehensive examination of the existing government-led conventional methodologies and AI based technological cardiovascular screening method utilized for cardiovascular disease screening in Rwanda. It is crucial to emphasize that the primary objective is to shed light on the cost-effectiveness and limitations inherent in each screening technique. Importantly, the review aims to draw meaningful comparisons between the costs and efficacy of these methods, furnishing valuable insights into the relative merits and drawbacks of conventional and technological cardiovascular disease screening strategies within the Rwandan context.

In delineating the scope of the comparison, it is imperative to explicitly state that the focus will be distinctly concentrated on comparing conventional screening methods against Lifesten's Trans dermal Optical Imaging (TOI AI) screening. It is noteworthy to clarify that Lifesten's TOI screening is a technologically advanced screening method internationally approved for cardiovascular screening purposes [21]. This ensures that the ensuing analysis delves into the contrasts between conventional and state-of-the-art technological screening, with a specific

emphasis on the merits and applications of Lifesten's TOI AI screening in the Rwandan context.

METHODOLOGY

Study Design

This mixed-methods study utilizes a systematic search and narrative synthesis, along with a primary research approach involving a qualitative method for cost analysis for benefit deduction from both review and interview responses.

Search strategy and narrative synthesis

A detailed literature search, spanning prominent databases such as PubMed, Google Scholar, and the Cochrane database, was complemented by a comprehensive review of reports from influential entities, including the Rwanda Ministry of Health, Rwanda Biomedical Centre, Rwanda Heart Foundation, and World Heart Federation. In navigating the expansive landscape of cardiovascular screening methods, our focus extended to studies and resources within the Rwandan context, emphasizing a nuanced examination of both government-led and technological approaches with a specific lens on their effectiveness and cost implications.

The deliberate exclusion of non-English literature was a methodological decision aimed at ensuring a uniform and coherent analysis. By prioritizing English-language literature, our methodology is strategically aligned with the intricacies of the local healthcare environment in Rwanda. This approach establishes a robust foundation for a systematic and comprehensive review, enhancing the relevance and applicability of our findings to address the unique healthcare challenges and opportunities prevalent in the Rwandan setting.

Despite the methodical approach used to search and synthesize the available literature, the review assumes a narrative form due to limitations in the quantity of available data. In this review, we adhered to a structured process, followed defined criteria, and provided valuable insights, even in the absence of sufficient data for a comprehensive systematic review.

The study selection process encompasses articles from 2013 to 2023, ensuring relevance. A list of search strings was developed to ensure thoroughness. The search targeted factors such as cost-effectiveness, health benefits, and screening efficiency. Truncations and wildcards were strategically employed to heighten search sensitivity. Some of the variants on the list include: "Cardiovascular Health Rwanda," "Government-led screening," and "technological solutions in health screening." ("Cardiovascular health" OR "heart health" OR "cardiovascular diseases") AND ("Rwanda"). ("Government-led screening" OR "public health screening" OR "government health initiatives") AND ("cardiovascular screening" OR "heart disease screening") ("Technological solutions" OR "health technology" OR "medical technology") AND ("screening methods" OR "health screening" OR "diagnostic technology") (Figure 1)

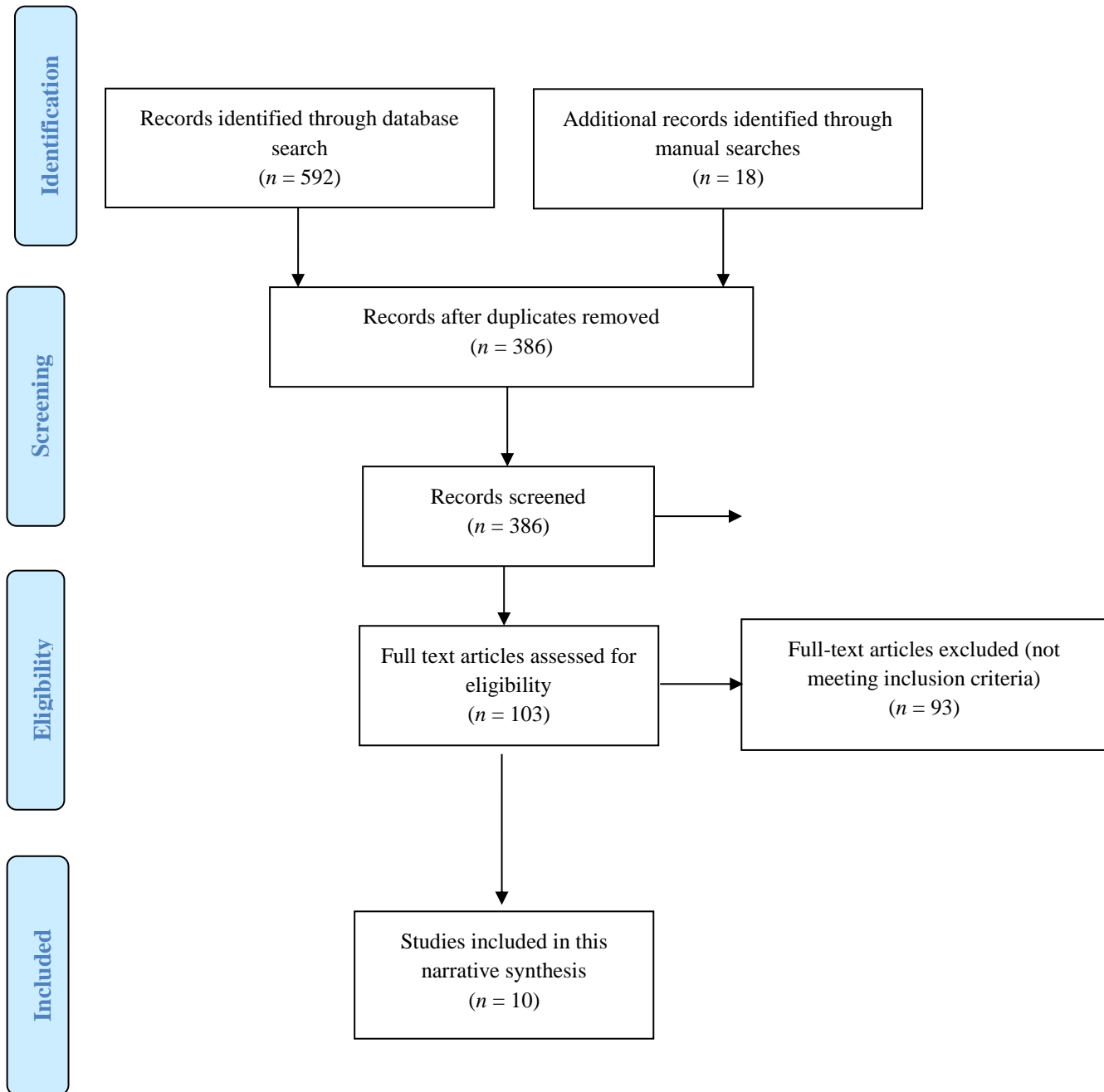


Figure 1: PRISMA framework of literature selection in this narrative synthesis

Cost-Benefit benchmark

To clarify, this research is characterized as a mixed-methods study with questions deduced from Asmah et al., 2020 for qualitative interview questions, to ensure peer-review quality.

Questions to explore the cost and benefits of traditional and Lifesten’s methods for cardiovascular care and management were directly adapted from Asmah et al., 2020. We selected two professionals from the NCD clinics of the Ministry of Health in Rwanda and Lifesten to address the study’s inquiries. Thematic analysis revealed recurring patterns in expert responses. Ethical clearance for this study was received from Rwanda National Research and Ethics Committee

RESULTS

Overview of government – led (conventional) cardiovascular screening in Rwanda.

One effective and widely used technique for cardiovascular disease (CVD) screening in Rwanda is the strategic use of community health workers (CHWs) to identify high-risk persons in communities. These CHWs play a critical role in early identification and subsequent referral for care and follow-up at health facilities by using a Body Mass Index (BMI)-based CVD risk assessment tool. This strategy has shown to be both workable and efficient, exhibiting adaptability in a variety of contexts that include both urban and rural areas[22].

The operational architecture for Rwanda’s cardiovascular disease screening program includes three community health workers

(CHWs) on average each village. Under this framework, every Community Health Worker (CHW) is accountable for screening 100 community members (CMs) in their particular villages, ranging in age from 35 to 74 [22]. In Rwanda, CHWs do not receive constant monthly salaries for their services [23], but their average monthly performance-based financing (PBF) wage is 4,553 RWF [24]. This is significantly less than the 160,000 RWF average monthly salary for a nurse [25]. These financial factors highlight the economic aspects of this significant community health screening approach and offer insights into cost dynamics of the government led screening approach [22].

Rwanda's government-led cardiovascular disease (CVD) screening program is very effective, especially when it comes to coverage and efficiency. This strategy, carried out by community health workers (CHWs), has shown to be effective and workable in both urban and rural environments. The accuracy, dependability, and cost-effectiveness of the BMI-based CVD risk assessment tool are taken into account while evaluating the study's efficiency. A remarkable positive connection between CHW-based and nurse-based CVD risk assessment in both rural and urban regions suggests that the BMI-based method is not only more cost-effective than its lipid-based equivalent, but also demonstrates excellent accuracy and reliability.

The government screening coverage is impressive covering rural and urban populations at 99.6% and 99.4%, respectively. However the coverage has not translated to utilization. For example, 15% of adults in Rwanda suffer from hypertension but just 3.7% of adults with hypertension are receiving therapy, and only 6.8% are aware that they have the illness [19], [20]. These findings highlight the screening method's ability to effectively reach a broad demographic while also targeting specific vulnerabilities [22].

Overview of Lifesten's technological cardiovascular screening in Rwanda

Lifesten Health is a dynamic wellness platform primarily in the form of a mobile application dedicated to transforming lives through comprehensive health solutions. Lifesten provides personalized guidance for workouts, stress relief, mindfulness, and nutrition. Besides this Lifesten Health also utilizes cutting edge transdermal optical imaging artificial intelligence to provide quick initial screening for cardiovascular health. The transdermal optical imaging technology that Lifesten uses has been licenced by the Nuralogix Coperation. The technology has been heavily researched and patented by the United States trademark office [21]. This technology is also internationally compliant with Personal Information Protection and Electronic Documents Act(PIPEDA), American Institute of Certified Public Accountants Service Organization Control 2(AICPA SOC2), Health Insurance Portability and Accountability Act(HIPAA), General Data Protection Regulation(GDPR) [26]. Locally Lifesten is the first AI based and AI led health startup to receive full data and technical compliance to operate in Rwanda.

Studies carried out in a number of nations, such as China, the United States, and Canada, have shown that TOI is a feasible and accurate method for obtaining accurate and legitimate measures of blood pressure and other vital cardiovascular parameters [24], [25], [26]. These results imply that TOI has potential as a useful tool for screening for cardiovascular disease. The potential utility of TOI is highlighted by its comparison to standard approaches observed in

various international settings. Tailoring TOI to Rwanda's distinct healthcare environment and demographics may facilitate its successful incorporation into cardiovascular screening guidelines, thereby providing a new and easily obtainable method to improve the early diagnosis and treatment of cardiovascular disorders in the country.

Apps such as Lifesten Health for smartphones are useful for tracking, managing, and keeping an eye on the risk factors and consequences of cardiovascular disease (CVD). By giving users easy access to tailored recommendations and feedback, these mobile apps support proactive health management [27].

Transdermal optical imaging and how it works

Transdermal optical imaging (TOI) is a new technology that measures blood pressure and other cardiovascular parameters by capturing changes of the blood flow in the face using a smartphone camera [28], [29]. The TOI employs sophisticated image processing and machine learning methodologies to extract the minute variations in facial skin tone resulting from variations in blood volume within the microvasculature [30].

Transdermal optical imaging (TOI) works by utilizing near-infrared light to penetrate the skin's surface and interact with underlying tissues and blood vessels. This technology captures light reflected from the skin and analyzes it to extract valuable physiological information.

How TOI works:

1. **Light Penetration:** Near-infrared light, which has longer wavelengths than visible light, is emitted by a light source and directed onto the skin's surface. This light is able to penetrate the outer layers of the skin, reaching underlying tissues and blood vessels.
2. **Tissue Interaction:** As the light travels through the skin, it interacts with various components such as blood vessels, capillaries, and tissues. Different components absorb and scatter light in unique ways based on their properties, such as oxygenation levels and blood flow.
3. **Reflection and Capture:** Some of the light is absorbed by the tissues, while the rest is reflected back to the surface of the skin. A specialized camera or sensor captures this reflected light, which contains valuable information about the underlying physiology.
4. **Analysis:** The captured light data is then analyzed using advanced algorithms and image processing techniques. By analyzing patterns in the reflected light, the system can extract physiological parameters such as blood flow, oxygenation levels, and tissue composition.
5. **Health Assessment:** Based on the analyzed data, the system can provide valuable insights into the user's health status. For example, in the case of cardiovascular health screening, TOI can assess parameters such as blood pressure, arterial stiffness, and vascular function, providing a non-invasive and convenient way to monitor cardiovascular health.

By offering a quick, comfortable, and contactless method of measuring blood pressure and other cardiovascular risk indicators like heart rate, heart rhythm, and heart rate variability, TOI can be used for the screening of cardiovascular diseases. Particularly in low-resource situations where access to traditional blood pressure devices may be restricted, TOI has the potential to enhance the prevention and management of cardiovascular diseases [31], [32].

The Lifesten App offers numerous benefits for cardiovascular health management. Firstly, it enables comprehensive evaluation through remote and continuous monitoring of vital indicators such as blood pressure, heart rate, and rhythm. This facilitates early detection of anomalies and provides a dynamic understanding of health markers. Real-time monitoring allows for timely interventions and enhances healthcare system responsiveness. Additionally, wearable technology and smartphone apps promote healthier lifestyles by offering personalized feedback and educational materials. The app's availability on any smartphone ensures accessibility for users who follow the provided demonstration.

Moreover, the app facilitates efficient communication between patients and medical professionals, leading to prompt diagnosis and treatment of cardiovascular disorders. The use of transdermal optical imaging (TOI) further enhances convenience, affordability, and accuracy in measuring cardiovascular parameters, making it particularly beneficial in low-resource settings. Overall, these technologies offer a comprehensive approach to cardiovascular health management, promoting proactive healthcare management and improving patient outcomes.

Cost – benefit analysis and effectiveness of traditional vs technological cardiovascular screening in Rwanda.

This section provides a comparative analysis of traditional and technological cardiovascular screening methods, focusing on accessibility, accuracy, time efficiency, and cost to users. Traditional screening often requires visits to health centers, posing challenges in remote areas, while technological screening via Lifesten's mobile app offers accessibility from anywhere with internet access.

Comparison between Lifesten's Cardiovascular Screening Technology Vs Government – led traditional screening approach

1. **Accessibility:** Traditional screening methods typically require individuals to visit health centers, posing challenges in remote areas. In contrast, technological screening through

Lifesten's mobile app allows individuals to access screening from anywhere with internet connectivity, including remote regions.

2. **Accuracy:** While traditional methods are known for their accuracy, they often require multiple tests to confirm results, leading to potential delays and inconvenience. In contrast, Lifesten's AI-powered transdermal optical imaging offers precise diagnostics with fewer tests, reducing the time and effort needed for screening. Typically, hospitals require one to three or more tests for confirmation, whereas Lifesten may only require one test initially, followed by another for confirmation. However, poor internet connectivity can impact Lifesten's efficacy, potentially necessitating more tests for confirmation. Nonetheless, each test only takes 30 seconds, minimizing the impact on time.

3. **Time Efficiency:** Traditional screening methods involve waiting times at clinics, adding to the overall time taken for the screening process. In contrast, Lifesten's technology enables quick screening through a 30-second facial scan, significantly reducing the time required for individuals to undergo screening.

4. **Cost to Users:** Traditional screening methods often entail significant expenses such as transportation fees and clinic charges, posing a financial challenge for many individuals. In contrast, Lifesten's screening via the mobile app offers potential cost savings or even no expenses at all, particularly as users are incentivized through the app. Financial implications for government screening include various factors such as transportation costs, waiting time, and the expense of traditional blood pressure machines. With Lifesten's pricing model featuring a test cost of \$0.6 USD, an estimated internet expense of \$0.2 USD, and the average cost of a smartphone around \$200 USD, budgeting for population screening becomes more manageable. Additionally, time spent by patients is reduced, minimizing time-related costs. If the mobile app can also be domiciled on patients' phones, transportation costs are eliminated entirely, and self-monitoring of conditions becomes possible. Moreover, it is envisioned that two phones can serve the same function as a BP machine, making data transmission and management even more easier.

Table 3: Comparing Costs of the 2 approaches(Per Person)

	Government-led screening	Technological screening (Transdermal Optical Imaging)
Transport costs	2 USD	0
Waiting costs	1 USD	0
Equipment and training	50 USD for bp machine 5 USD for training	100 USD phone 0.6 USD screening 0.2 USD internet
Results	Blood pressure. Systolic blood pressure Diastolic blood pressure, heartbeat	Mental stress index, facial skin age, cardiovascular disease risk, cardiac workload, vascular capacity, breathing rate, heart pulse, body mass index, heart rate variability, stroke, irregular heart beat count, systolic blood pressure, diastolic blood pressure, general wellness score, mental score, physiological score, heart attack risk
Total Cost	58 USD	100.8 USD

Table showing comparison cost and result comparison between government-led and technological screening methods. The BP machine, training and phone costs are not recurring expenditure but rather capital costs. The are one-off purchases.

Benefits of Early Detection and Remote Monitoring with Lifesten Mobile App

- 1. Early Detection:** Early detection of cardiovascular issues allows for timely intervention, reducing the risk of complications and saving costs in the long term. Lifesten's technology facilitates early detection through remote and ongoing monitoring, potentially leading to significant cost savings.
- 2. Reduced Hospital Admissions:** Preventive measures enabled by early detection can lead to a decrease in hospital admissions for cardiovascular-related issues. By identifying and addressing health concerns proactively, Lifesten's screening may help reduce the burden on healthcare facilities and resources.
- 3. Improved Productivity:** Timely detection and management of health issues contribute to improved productivity as individuals can maintain their health and continue with their daily activities without interruptions. Lifesten's technology allows individuals to monitor their health conveniently, reducing the impact of health issues on productivity.
- 4. Reaching the Unreached Populations:** Lifesten's mobile-based screening approach makes it easier to reach unreached populations, including those in remote areas. With just a smartphone and internet connectivity, individuals can undergo screening without the need to visit healthcare facilities, ensuring broader access to cardiovascular health services. Internet accessibility is increasing in Rwanda, enabling more widespread access to the mobile app for any trained Community Health Worker.

Table 4: Comparative Analysis of Traditional Blood Pressure Clinics vs. Lifesten's Transdermal Optical Imaging AI

Criteria	Traditional Blood Pressure Clinics	Lifesten's Transdermal Optical Imaging AI
Accessibility	Limited access in remote areas	Mobile-based, potentially reaching remote regions
Accuracy	Standard methods with known accuracy	Utilizes AI for precise diagnostics. However Prone to inaccurate results if the lighting and internet are not optimal
Time Efficiency	Often involves waiting times at clinics	Quick screening through a 30-second facial scan
Cost to Users	May incur transportation costs and clinic fees	Potentially lower cost or no cost if incentivized through the app

This analysis demonstrates the advantages of Lifesten's technological approach over traditional cardiovascular screening methods in Rwanda. Lifesten's mobile-based screening offers enhanced accessibility, accuracy, time efficiency, and cost-effectiveness, making it a promising solution for improving cardiovascular health outcomes in the country.

Cost-Benefit Analysis

- **Government-led screening:** The total cost per screening is \$58 USD, and it provides basic cardiovascular health information.
- **Technological screening:** The total cost per screening is \$100.8 USD, but it provides comprehensive cardiovascular health information.

While the government-led screening approach is cheaper, it only provides limited information. In contrast, the technological screening approach is more expensive but provides significantly more comprehensive and detailed cardiovascular health data. Therefore, the technological screening approach may offer better value in terms of the depth of information provided, potentially leading to more accurate diagnoses and targeted interventions, ultimately resulting in improved health outcomes.

Challenges and Opportunities in both of the Cardiovascular Disease Screening approaches

Government Approach Challenges:

1. Limited Reach in Remote Areas: One of the significant challenges faced by government health initiatives is the limited reach in remote areas due to infrastructure limitations. Conducting health screenings in these regions is often hindered by geographical barriers, making it difficult to provide essential healthcare services to residents. To address this challenge, implementing mobile health units or utilizing technology for

remote screening camps could be a potential improvement. These approaches can help overcome geographical constraints and ensure that healthcare reaches even the most remote communities.

2. Resource Constraints: Another challenge encountered by government health initiatives is resource constraints, which restrict the scale and frequency of screenings. Limited resources can hinder the effectiveness of health programs and limit their impact on public health outcomes. To mitigate this challenge, exploring public-private partnerships and leveraging technology for broader coverage could be beneficial. By partnering with private organizations and utilizing innovative technologies, governments can maximize their resources and extend the reach of their health initiatives to a larger population.

Technological Solutions Challenges

1. Digital Literacy Barriers:

One of the challenges faced by technological solutions in healthcare is the limited digital literacy among certain individuals, particularly in rural areas. Many people lack the necessary skills to effectively use digital health tools, which can hinder their ability to access and benefit from these technologies. To address this challenge, conducting community-level digital literacy programs alongside tech implementations could be a potential improvement. By educating communities about digital health tools and providing training on how to use them, governments can empower individuals to take control of their healthcare.

2. Infrastructure Limitations: Infrastructure limitations, such as poor connectivity or limited smartphone access, pose significant challenges to the adoption of technological solutions in healthcare. In many regions, inadequate infrastructure excludes certain population segments from accessing digital health services, limiting their ability to benefit from these innovations. To overcome this challenge, exploring hybrid models that combine traditional methods with technology for inclusivity could be beneficial. By integrating technology into existing healthcare

infrastructure while ensuring alternative access points for those with limited connectivity or smartphone access, governments can enhance the inclusivity of their healthcare initiatives and ensure equitable access to healthcare services for all.

Opportunities for Integration:

Government-Backed Awareness Campaigns offer a significant opportunity to enhance awareness of the benefits of technological solutions in healthcare. Collaborating with government health campaigns provides a platform to promote innovative health tech tools like Lifesten. By integrating Lifesten into government initiatives, a wider audience can be reached, leading to increased adoption and utilization of the platform.

Data Sharing for Improved Insights presents another opportunity for enhancing healthcare outcomes. By integrating government health data with technological platforms like Lifesten, comprehensive insights can be obtained. Establishing secure data-sharing protocols is essential to combine health records with Lifesten's AI, enabling more personalized and effective healthcare interventions.

Training Healthcare Workers is crucial for maximizing the impact of technological solutions within government health infrastructure. Government health systems involve a network of healthcare professionals whose proficiency with health tech tools can significantly impact their effectiveness. By providing training programs for healthcare workers on the efficient use and promotion of technological tools like Lifesten, their adoption can be accelerated, leading to improved patient outcomes.

Incentivizing Health Tech Adoption through government initiatives offers yet another opportunity to promote the use of health tech solutions among both users and providers. By collaborating with government programs, incentives can be offered through the Lifesten app, encouraging users to adopt and engage with the platform. Additionally, incentives for healthcare providers can further promote the integration of Lifesten into routine healthcare practices, ultimately leading to better health outcomes for the population.

Conclusions and recommendations

Cardiovascular health emerges as a paramount concern globally, with Rwanda confronting it as a predominant cause of mortality. Effective screening, treatment, and management are indispensable in alleviating the burden of cardiovascular diseases. While conventional methods have shown effectiveness, the technological approach offers notable efficiency advantages, necessitating less equipment and training. However, the challenge lies in the prevalence of digital illiteracy, which poses a barrier to the widespread adoption of technological screening solutions. Furthermore, the scarcity of materials and healthcare providers remains a persistent challenge for conventional screening methods. Mitigating these challenges demands substantial investments in digital literacy initiatives and intensified training for healthcare providers. By addressing these critical areas, Rwanda can significantly diminish the mortality and morbidity burden associated with cardiovascular diseases.

The integration of technological solutions, such as Lifesten Health, into cardiovascular disease (CVD) screening in Rwanda presents a promising avenue for enhancing accessibility, efficiency, and effectiveness. While traditional screening methods have demonstrated efficacy, the adoption of innovative approaches like

Lifesten offers distinct advantages, particularly in terms of cost-effectiveness and convenience.

Lifesten's utilization of transdermal optical imaging (TOI) technology showcases a transformative shift in cardiovascular screening, offering a contactless and efficient method for measuring blood pressure and other vital parameters. Studies across various nations have validated TOI's accuracy and feasibility, underscoring its potential as a valuable tool for early detection and management of CVD.

Cost analysis reveals that Lifesten's approach entails minimal direct screening costs compared to traditional methods, which require substantial investments in equipment and training. Moreover, Lifesten eliminates the need for transportation costs, as patients can conveniently use the app from the comfort of their homes. This cost-effectiveness not only reduces financial barriers but also promotes equitable access to screening services across diverse demographic groups.

Furthermore, the integration of wearable technology and smartphone apps into cardiovascular screening not only enhances the accuracy of measurements but also empowers individuals to take proactive steps towards improving their cardiovascular health. By providing personalized feedback, educational resources, and facilitating communication between patients and healthcare providers, Lifesten fosters a holistic approach to cardiovascular wellness.

Future research endeavors should focus on evaluating the long-term impact of digital literacy programs and healthcare provider training initiatives on cardiovascular health outcomes in Rwanda. Moreover, exploring innovative strategies to enhance the accessibility and affordability of technological screening solutions warrants further investigation.

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