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Telemedicine in sickle cell care: A global equity systematic review.

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Systematic Review

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Abstract

Background: Sickle Cell Disease presents complex healthcare challenges, particularly in regions with limited access to specialized care. Adopting telemedicine as a healthcare delivery model offers new opportunities to bridge care gaps, improving access to early diagnosis, treatment adherence, and patient monitoring.

Methodology: This study conducted a systematic review using databases to analyse telemedicine's role in SCD management. Out of 112 studies reviewed, 27 met the inclusion criteria. The study applied a comparative healthcare framework, assessing patient and caregiver satisfaction, accessibility barriers, and healthcare system integration in both developed and developing countries.

Results Discussion: Findings suggest that patients in developed countries report higher satisfaction with telehealth services, largely due to strong digital infrastructure, insurance support, and established telemedicine frameworks. Conversely, developing nations face obstacles such as unreliable internet, high telehealth costs, and low adoption rates among healthcare providers. Regardless of location, patients and caregivers prefer a hybrid approach, where telemedicine complements in-person care rather than replacing it entirely.

Conclusion and Recommendations: For telemedicine to be a sustainable healthcare model, governments and healthcare organizations must invest in digital infrastructure, make telehealth services more affordable, and provide training for both providers and patients. Also, to achieve sustainable integration of telemedicine into SCD care, healthcare models must prioritize equitable access, financial support mechanisms, and workforce training. Policy innovations and strategic investments in digital health infrastructure are essential to ensure telemedicine becomes a scalable and patient-centered solution for global SCD management.

Introduction

Sickle Cell Disease (S.C.D.) is still a major global public health concern, particularly in areas with a high frequency of the sickle cell trait, such as Sub-Saharan Africa, parts of the Middle East and India. SCD, characterized by aberrant hemoglobin production, causes a variety of health issues, including recurring discomfort, anaemia, and multiorgan damage. (Piel et al., 2017). Early diagnosis and monitoring are critical to mitigating these complications and improving patient outcomes.

Telemedicine has emerged as a transformative tool in healthcare delivery. By leveraging technology, telemedicine facilitates remote consultations by providing opportunities for improved access to quality care (World Health Organization [WHO], 2020). Telemedicine is feasible and acceptable for both adult and pediatric SCD patients, with high follow-up rates and improved medication adherence (Curfman et al., 2022).

As the application of telemedicine in diagnosing SCD has shown promise, particularly in overcoming geographical and infrastructural barriers, developed countries have integrated telemedicine into standard care for SCD, demonstrating its potential for scalability and effectiveness (Kruse et al., 2018). On the contrary, developing countries have faced unique challenges in implementing telemedicine, including limited technological infrastructure, unreliable internet connectivity, and financial constraints (Ryu, 2012).

Problem Statement

Despite advances in medical care, access to specialised treatment remains limited, especially in low-resource settings. Telemedicine has emerged as a potential solution to bridge these gaps, but its effectiveness and challenges in SCD management are not well-documented.

This review aims to systematically evaluate the application of telemedicine in SCD care, focusing on its effectiveness by comparing telemedicine advancements across diverse settings. This study also aims to identify barriers to its implementation in both developed and developing countries.

Aims and objectives

This systematic review aims to provide a comparative review of telemedicine applications in SCD care across developing and developed countries.

General Objective

To conduct a comprehensive systematic review of the application and effectiveness of telemedicine in managing Sickle Cell Disease (SCD) across developed and developing countries, with the aim of identifying best practices, challenges, and opportunities for improvement in global healthcare delivery.

Specific Objectives

1. 1. To evaluate the effectiveness of telemedicine in improving access to SCD care: Evaluate the frequency and patterns of telemedicine use among individuals with Sickle Cell Disease (SCD) across developed and developing countries, focusing on the accessibility by SCD patient
2. 2. To assess patient and caregivers' satisfaction with telemedicine services; Investigate patient, caregiver, and healthcare provider satisfaction and usability of telemedicine services in SCD care, comparing outcomes between telemedicine and in-person visits.

3. 3. To identify barriers and facilitators of telemedicine adoption in SCD care; Determine the barriers to telemedicine adoption (e.g., technological, infrastructural, economic) and facilitators (e.g., policy support, internet access) in both developed and developing countries.
4. 4. To compare telemedicine outcomes between developed and developing countries; Examine the effects of telemedicine on clinical outcomes for SCD patients, including management of acute and chronic pain, medication adherence, and overall disease management
5. 5. To identify the role of AI in health and telehealth innovations in SCD treatment.

Methodology

Research Design

This review looks at the impact of mobile health (mHealth), telecare, and telemedicine in improving healthcare delivery for people with sickle cell disease (SCD). The review investigates both benefits and challenges of telehealth in SCD diagnosis and management, while also exploring barriers to adoption among diverse populations including patients, caregivers, and parents.

The objectives of the review are to:

- Evaluate the effectiveness of telemedicine in SCD care delivery.
- Assess patient and caregiver satisfaction with telehealth services.
- Identify barriers and facilitators to telemedicine implementation.
- Examine the role of artificial intelligence (AI) in telehealth innovation.
- Explore disparities in telemedicine adoption across demographic groups.

Search Strategy

A systematic and structured search approach was devised to ensure thorough and unbiased coverage of the relevant literature. The PICO (Population, Intervention, Comparison, and Outcome) framework was used to frame the study issue as follows:

"How is telemedicine applied in the management of sickle cell disease in developing and developed countries, and what are the associated benefits and challenges?"

Literature was retrieved using **Harzing's Publish or Perish software** and **Google Scholar**, as well as through searches of the following academic databases:

• PubMed

• ScienceDirect

• Scopus

• CINAHL

A combination of keywords and Boolean operators was used to broaden and refine the search. Key terms included: *"telemedicine," "telehealth," "mHealth," "sickle cell disease," "AI in healthcare," "remote monitoring," "caregiver satisfaction," "barriers to adoption,"* and related synonyms.

Table 1
Database Summary Table

Database	Search Terms Used	Articles Retrieved
PubMed	"telemedicine" AND "sickle cell disease"	28
ScienceDirect	"mHealth" OR "telecare" AND "SCD"	23
Scopus	"AI in telehealth" AND "sickle cell"	31
CINAHL	"remote care" OR "virtual consultation" AND "sickle cell"	18
Google Scholar	General search using Publish or Perish	12
Total		**112**

Study Selection and Inclusion/Exclusion Criteria

Studies were included if they:

- Focused on the application of telehealth or telemedicine in SCD care.
- Were published in English between 2020 and 2025.
- Addressed patient or caregiver outcomes, barriers to adoption, or AI integration in telehealth.

Excluded studies:

- Did not directly relate to SCD or telemedicine.
- Were not peer-reviewed (e.g., opinion pieces, editorials).
- Focused solely on unrelated chronic diseases or general digital health trends.

PRISMA Flow Diagram

A PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram was used to document the screening process. The diagram details the identification, screening, eligibility, and inclusion phases of study selection.

Data Extraction and Quality Assessment

Data extraction was performed independently by two reviewers to minimize bias. Extracted data included study design, sample size, intervention type, population demographics, key outcomes, and limitations.

The **Cochrane Risk of Bias Tool** was used to assess methodological quality. Each included study was evaluated across domains such as selection bias, performance bias, detection bias, attrition bias, and reporting bias. Results were summarized in a tabular format to improve clarity.

Statistical Analysis

Data were synthesized using a **random-effects model** to account for expected heterogeneity across studies. Meta-analysis was conducted where applicable using **RevMan software**, and heterogeneity was assessed using the **I^2 statistic**.

Subgroup analyses were performed to compare outcomes across developed and developing countries. Additional narrative synthesis was applied to studies not suitable for meta-analysis due to design variation or lack of comparable data.

Table 1.0 shows a summary of articles retrieved from the various databases.

Following the retrieval of articles, a set of inclusion and exclusion criteria was applied to refine the selection. Studies published between 2020 and 2025 were included to ensure the relevance of recent research. The screening and selection process followed a structured approach. Initially, 112 articles were retrieved through Publish or Perish software. After removing duplicates and unrelated studies, 85 articles remained. These were further screened based on their titles and abstracts, reducing the number to 40 studies. Full-text screening was conducted to ensure relevance, and 25 articles were found to fully align with the research topic. Additionally, two more articles were manually identified through targeted database searches, bringing the total number of included studies to 27.

Furthermore, data extraction was conducted using a structured form, documenting key details such as study title, author(s), year, country, telemedicine intervention used, SCD diagnostic method, and key findings.

Quality assessment

To ensure the methodological rigor and reliability of the included studies, we conducted a quality assessment using the Cochrane Risk of Bias Tool. The tools were selected based on the study designs of the included research. Thus, we used a specific Cochrane Risk Bias Tool tailored to the study designs, including randomized controlled trials (RCTs), cohort studies, and qualitative research. The majority of the included studies were of low bias indicating high methodological quality and strong evidence as shown in

Descriptive Statistics of Included Studies

The review includes 27 studies on the application of telemedicine, telecare and telehealth in sickle cell disease (SCD) management. Out of the 27 included studies, 15 were conducted in developed countries (USA, UK, Bahrain, Saudi Arabia), and 12 conducted in developing countries (India, Nigeria, Uganda, Sub-Saharan Africa 12 articles studied). The methods employed across these studies included; quantitative (*n* = 10, (37.0%)), qualitative (*n* = 9, (33.3%)), mixed-methods (*n* = 5 studies (18.5%)), Systematic Reviews: 3 studies (11.1%).

Discussions/Results

Theoretical Framework The findings are interpreted through the lens of the Technology Acceptance Model (TAM), which posits that perceived usefulness and ease of use are key determinants of telemedicine adoption. In developed countries, high satisfaction with telemedicine can be

attributed to its perceived usefulness in reducing travel time and costs. In contrast, low adoption in developing countries may be due to perceived barriers such as unreliable internet and lack of digital literacy.

Effectiveness of Telemedicine in Providing SCD Care. Telemedicine has significantly transformed healthcare delivery for individuals with Sickle Cell Disease (SCD), offering improved access to care, increased treatment adherence, and enhanced patient satisfaction (Ekeland et al., 2010). Findings from various studies indicate that telemedicine is a viable and effective approach to managing chronic conditions such as SCD, especially in both developed and developing regions.

Mobile health apps have played an important role in improving healthcare delivery, lowering costs, and increasing accessibility, safety, and quality of care (Hankins et al., 2022). Hankins et al. discovered a significant absolute mean increase of 16.3% in adherence, resulting in a 25% reduction in pain admissions. Lydia et al. (2020) found that telemedicine helped adults with SCD make better use of their time, with patients spending less personal or work time attending consultations. Participants also reported feeling safer after using telemedicine, which allowed them to forgo taking pain medication before driving to appointments. Several studies have demonstrated significant reductions in emergency department visits among SCD patients utilizing telemedicine, emphasizing its impact on early intervention and effective pain management (Badway et al., 2023; Marsha et al., 2022). For example, Pecker et al. (2023) found that SCD patients rated telemedicine highly for routine care, demonstrating its potential to serve as an alternative to in-person consultations. Telemedicine services have also resulted in increased specialist consultations, particularly for patients in rural and underserved regions, addressing long-standing accessibility challenges (WHO, 2022).

Telemedicine has increased adherence to treatment among SCD patients. Hankins et al. (2023) reported a 16.9% increase in adherence to hydroxyurea. The positive effects of telemedicine are further reflected in high patient satisfaction, with the majority of SCD patients reporting positive experiences. Caregivers and healthcare providers also recognize its efficiency, despite limitations in performing certain physical assessments (Hankins et al., 2022; Speller-Brown, 2023).

Benefits of Telehealth on Patient and Caregiver Satisfaction Despite some challenges, several benefits contribute to overall positive patient and caregiver experiences with telehealth.

Reduced Travel Burden

Caregivers, especially for children or elderly patients with SCD, find telehealth beneficial in reducing travel-related stress and costs. Shaner et al. (2021, USA) reported that caregivers traveling long distances for SCD check-ups found telehealth a major relief, reducing time off work and transportation expenses.

Continuity of Care and Monitoring

During the COVID-19 pandemic, telemedicine played a crucial role in maintaining access to SCD management. Patient satisfaction with telemedicine was high, with ~ 90% of patients reporting positive experiences, particularly in developed countries (Treadwell et al., 2024). Treadwell et al. also found that patients and caregivers in larger hospitals adapted well to telehealth and even preferred a hybrid model (telehealth + in-person visits).

In developing countries, mobile health (mHealth) applications help caregivers track symptoms and medication schedules, improving adherence to treatment regimens. Jacob et al. (2023, USA) found that telehealth improved caregiver psychological well-being as the burden of in-person clinic visits lessened.

Disparities in Telemedicine Adoption Across Developed and Developing Countries Despite the advantages of telemedicine, disparities in adoption remain a significant challenge. In developed countries, telemedicine adoption is facilitated by robust digital infrastructure and policy support. Medicare and Medicaid expanded telehealth coverage, leading to a surge in utilization (Waseem et al., 2022). In contrast, developing countries face infrastructural challenges such as limited internet connectivity, lack of mobile devices, and insufficient government investment (WHO, 2022).

Studies highlight a “digital divide” in telemedicine access, with low-income and rural populations in developing regions struggling with digital literacy and affordability constraints (Ekeland et al, 2010; Lee et al, 2024). Additionally Jacob et al (2023) noted that the lack of physical exams and difficulty building trust via telemedicine were concerns for around 25% of participants.

Table 3
Trends Between Developing and Developed Countries

Parameter	Developed Countries	Developing Countries
Technology Adoption	Telehealth employs technologically driven diagnostics	Limited to basic models such as video calls
Infrastructure	State-of-the-art digital health industry	Inadequate digital health infrastructure
Regulatory & Policy Support	Well integrated into national healthcare policies	Inadequate policy support
Telemedicine Usage	Routine consultations and chronic care	Mostly for health education and emergency response
Barriers	Rural disparities, technology costs, cybersecurity	Poor connectivity, unskilled personnel

Patient and Caregiver Satisfaction with Telehealth Services Telemedicine, telecare, and telehealth have emerged as transformative tools for improving healthcare access and managing chronic conditions like SCD. A key objective of implementing telehealth services is to assess patient and caregiver satisfaction, which influences adoption, engagement, and sustainability.

Accessibility and Convenience

Patients in developed nations appreciate the convenience of telehealth for routine consultations, hydroxyurea management, and follow-ups. Studies such as Treadwell et al. (2024, USA) indicate high satisfaction due to reduced travel time, easier appointment scheduling, and lower transportation costs. Jacob et al. (2023) reported that 81% of patients were willing to partake in telemedicine visits because of its convenience. In developing countries, telehealth is seen as a lifeline in remote areas. However, poor internet access, power outages, and low digital literacy negatively affect satisfaction (Chitungo et al., 2021).

Patient-Care Provider Interaction

In developed nations, patients find telehealth effective for follow-ups and chronic disease management but less effective during crises. Pecker et al. (2020, USA) found that telemedicine was valued for efficiency but lacked the personal connection of in-person visits. In developing countries, telehealth adoption is still growing, and trust in virtual consultations is lower. Caregivers in Nigeria and Uganda (Nlemadim et al., 2021; Obeagu et al., 2022) expressed concerns about misdiagnosis and inadequate care.

Financial Considerations

In developed countries, telehealth services are often covered by insurance or government programs, reducing cost burdens. Reeves et al. (2023, USA) found that Medicaid beneficiaries used telehealth more due to coverage and ease of scheduling. In developing countries, costs for internet data and smartphones place an additional financial burden on patients. Even in the U.S., lower-income families face digital access issues, which are more pronounced in low-income settings (Jacob et al., 2022).

Digital Literacy

Badawy et al. (2022, USA) revealed high adoption rates among younger patients. However, elderly caregivers or those with low digital skills struggle to use telehealth platforms. In rural Africa and South Asia, low digital literacy significantly affects satisfaction, making telehealth less user-friendly.

The role of AI in health and telehealth innovations in SCD treatment; The healthcare sector has witnessed significant innovations with the integration of Artificial Intelligence (AI) in telehealth. AI-powered telehealth platforms have transformed the way healthcare services are delivered, making them more accessible, efficient, and personalized in the developed nations and potentially in the third world nations. There is an infinite growth potential afforded by the combination of AI and telemedicine (Amjad et al 2023). Also Alturaiki et al. reported 90.9% of their patients agreed that their AI chatbot made managing β-thalassemia easier, and 82.4% of the patients believed that the chatbot

would enable more efficient management of β-thalassemia. Artificial Intelligence (AI) is transforming the landscape of sickle cell disease and already making great strides by:

Monitoring disease progression through medical imaging and real-time data, Predicting pain crises and improving personalized treatment. Assisting in drug discovery and optimizing clinical decision-making. Building trust with healthcare providers through explainable AI models. Enabling diagnosis and enhancing genetic counselling through virtual sessions (Ganapathy 2021)

These innovations will not only improve the outcomes for sickle cell patients but also pave the way for broader applications of AI in healthcare.

To fully harness the potential of telemedicine in SCD treatment, it's crucial to address the associated risks. Key challenges that must be overcome include:

- - Compromising the accuracy and reliability of health data by not having the means to integrate AI in the fledging EHR System especially in the low income countries and the same time considering data privacy of patients across all adopted telehealth platforms.
- - The financial repercussions in adapting AI into treating SCD through telecare on all health stakeholders need to be addressed.

By tackling these challenges, we can ensure the successful integration of Artificial Intelligence in telemedicine into the management of sickle patients, improving patient outcomes and care in the end.

Table 4
Results Mapping Table

Objective	Key Finding	Alignment
Evaluate the effectiveness of telemedicine	25% reduction in admissions for pain in developed countries	High
Assess patient satisfaction	with ~ 90% of patients reporting positive experiences, particularly in developed countries	High
Identify barriers to adoption	About 25% (n = 24) said it was more difficult to establish trust through telemedicine, and the absence of a physical examination was a drawback.	High
Explore AI in SCD treatment and diagnosis	AI models (e.g., ResNet-50) achieve 94.9% accuracy in SCD detection and 90.9% acceptance to use AI chatbot.	High

Conclusion

Telemedicine is an invaluable tool for improving healthcare access for individuals with Sickle Cell Disease (SCD), especially in areas with limited in-person medical care. It enables remote consultations, patient monitoring, and better treatment adherence. However, its effectiveness and acceptance differ across healthcare systems. Developed countries, with well-integrated telehealth systems, generally see higher patient and caregiver satisfaction. In contrast, developing countries face challenges such as unreliable internet, high costs, and lack of standardized policies.

Key findings include a preference for hybrid care models, combining telehealth with in-person consultations to enhance patient engagement and care continuity (Treadwell et al., 2024). To optimize telemedicine for SCD management, the study recommends expanding digital infrastructure, subsidizing costs, standardizing policies, and enhancing provider training (Kruse et al., 2018). By addressing infrastructure gaps and policy limitations, telemedicine can become a sustainable and patient-centered solution for SCD care globally (Reeves et al., 2023).

Recommendations for practice:

- To facilitate telemedicine, developing nations should make investments in more robust digital health and internet infrastructure by government.
- Integrate Telemedicine into Healthcare: To improve access and utilization, governments should formally incorporate telemedicine into their health policy through the Health Ministry.
- Educate Healthcare Professionals: To effectively employ telemedicine in the management of sickle cell disease, physicians and Nurses must receive the appropriate training by the Healthcare stakeholders.
- Make Services Affordable: Telemedicine should be freely accessible and reasonably priced, particularly for patients with limited financial resources by the Government.
- Assure Data Security: Strict safeguards should be in place to preserve medical records and patient privacy by the Government.
- Utilize Advanced Technology: To enhance SCD diagnosis and therapy, artificial intelligence (AI) and digital tools should be investigated by the government security expert.
- Promote International Partnerships: To exchange information and enhance telemedicine services, developed and developing nations should work together.
- Encourage More Research: To fully comprehend the long-term effects, more research should be done.

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Figures

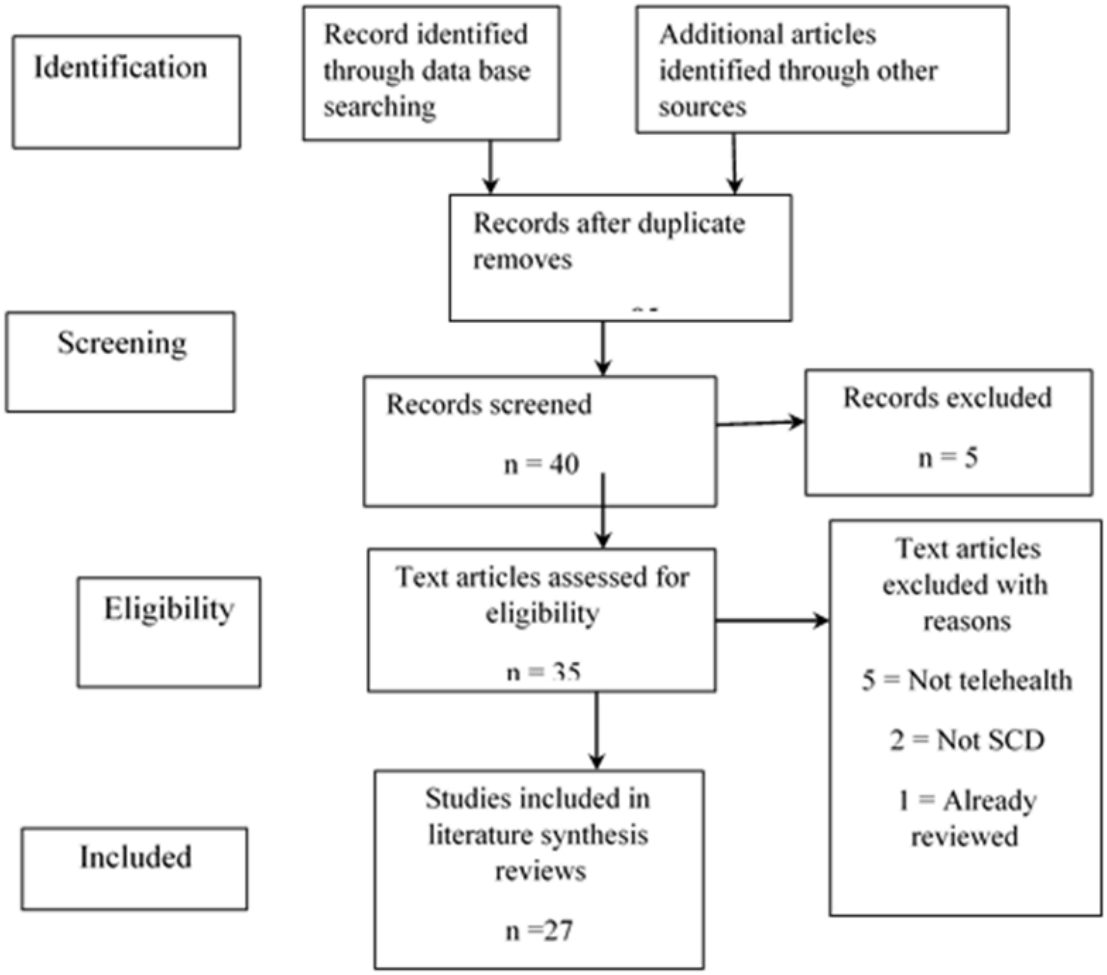


Figure 1

PRISMA Flow Diagram



Figure 2

Summary of Cochrane Bias assessment for Randomized Control trial studies (ROB 2

Panel A: *Results of the Cochrane Risk of Bias assessment tool for randomized controlled trials.*

***Panel B**: Risk of bias assessment for domains. Points evaluated: randomized process, deviations from intended interventions, missing outcome data, measurement of the outcome, selection of the reported result, and overall risk of bias*

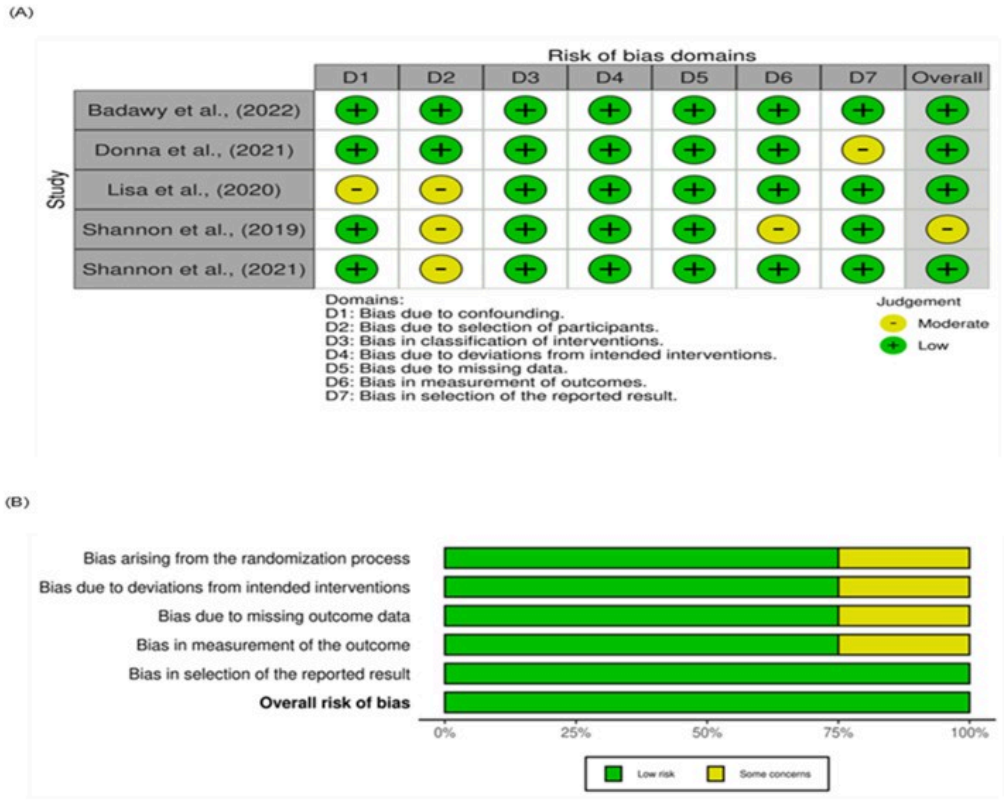


Figure 3

Results of Cochrane Risk Bias assessment tool for Non-randomized studies of Intervention (ROBINS-1)

Panel A: Results of the Cochrane Risk of Bias assessment tool for non-randomized studies of intervention, Panel B: Risk of bias assessment for domains. Points evaluated: confounding, selection of participants, classes of intervention, missing data, outcome measures, and overall risk of bias

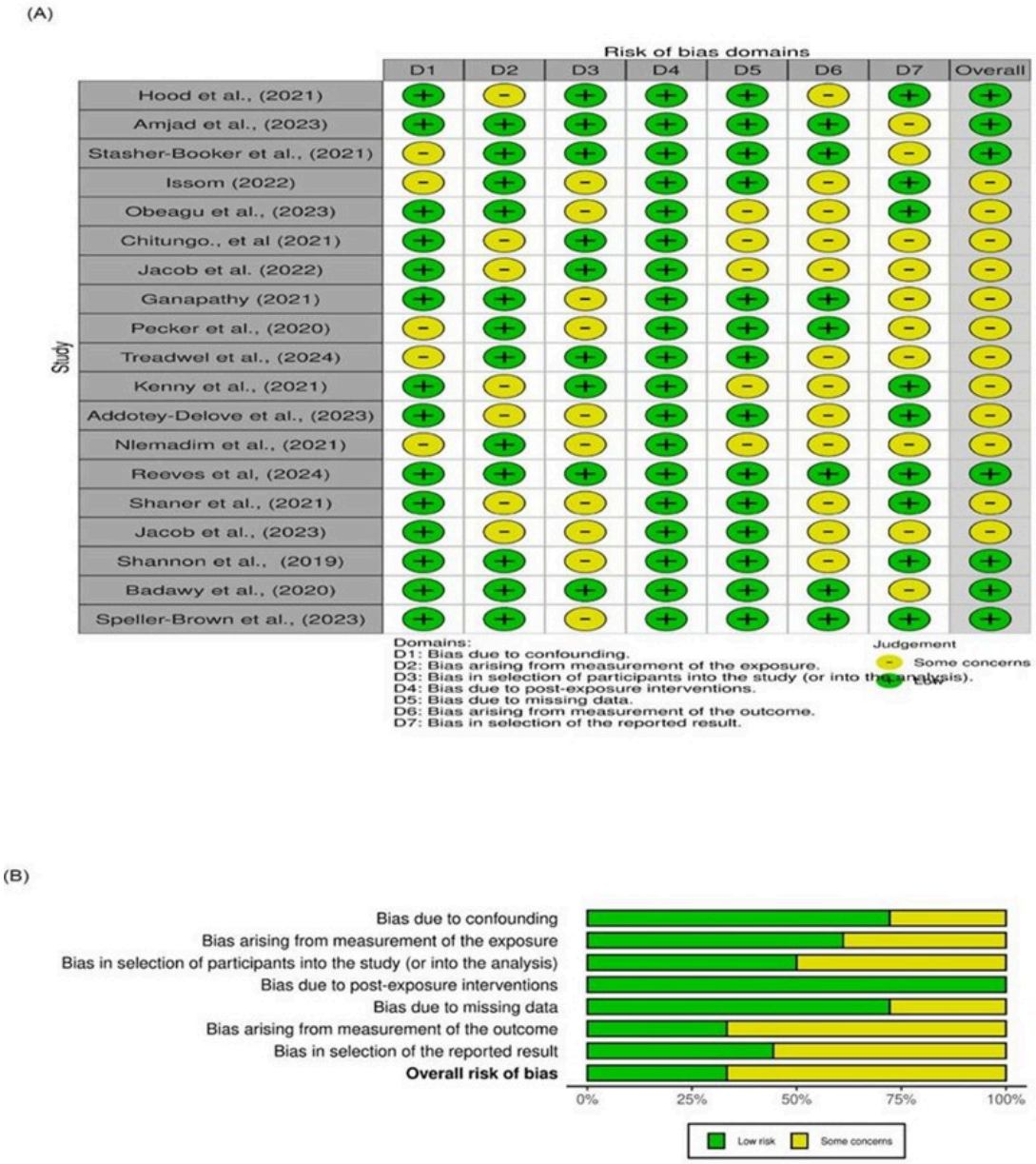


Figure 4

Results for Cochrane Risk of Bias in Non-Randomized Studies- of Exposures (ROBINS-E)

Panel A:*Results of the Cochrane Risk of Bias assessment tool for non-randomized studies of exposure. Panel* ***B****: Risk of bias assessment for domains. Points evaluated: confounding, pre-intervention exposure, selection of participants, post-intervention exposure, missing data, outcome measures, and overall risk of bias.*

Supplementary Files

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