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Simplified echocardiography as a tool for community screening of rheumatic heart disease: A systematic review and meta-analysis on the role of nonexpert operators

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Abstract: Rheumatic heart disease (RHD) remains a major global health challenge, particularly in low- and middle-income countries with limited access to expert echocardiography. Simplified echocardiography performed by non-expert operators is a scalable solution for community-level screening. This systematic review and meta-analysis aim to evaluate the diagnostic accuracy, feasibility, and effectiveness of non-expert-led echocardiographic screening using simplified protocols. A systematic search of PubMed, Web of Science, Scopus, ProQuest, and ScienceDirect identified eligible studies. Inclusion criteria encompassed studies evaluating non-expert-operated echocardiography for RHD screening. A bivariate random-effects meta-analysis estimated pooled sensitivity, specificity, and area under the curve (AUC), adhering to PRISMA guidelines. Eight studies met inclusion criteria, involving various non-expert operators (e.g., nurses, medical students, community health workers). Pooled sensitivity and specificity for the MR ≥ 1.5 cm or any AR threshold were 0.76 (95% CI: 0.63–0.82) and 0.86 (95% CI: 0.79–0.90), with an AUC of 0.88 and SROC curve I^2 of 96%. For the MR ≥ 2 cm or any AR threshold, specificity rose to 0.94 (95% CI: 0.91–0.96) but sensitivity dropped to 0.57 (95% CI: 0.42–0.71), with an AUC of 0.91 and SROC curve I^2 of 91%. Substantial heterogeneity was observed, likely from variations in operator training and protocols. Simplified echocardiography with proper training is a promising screening method for RHD in resource-limited areas. Despite variability in image acquisition and operator performance, task-sharing models can significantly improve RHD detection. Further research is needed to refine screening protocols and assess cost-effectiveness in large-scale programs.

Keywords: Community screening, Echocardiographic screening, Handheld ultrasound, Nonexpert operators, Rheumatic heart disease, Task shifting.

1. Introduction

Rheumatic heart disease (RHD) remains a significant global health burden, particularly in low- and middle-income countries, where limited healthcare resources and inadequate screening programs contribute to its persistence [1]. The disease, caused by an abnormal immune response to Group A Streptococcus infections, affects over 40.5 million people worldwide and results in approximately 305,000 deaths annually [1, 2]. South Asia bears a disproportionate share of this burden, accounting for more than 50% of global RHD-related deaths [3]. Despite declining mortality trends due to improvements in RHD management, the prevalence of the disease continues to rise, underscoring the urgent need for enhanced preventive strategies [3]. The long-term complications of RHD, including heart failure and stroke, contribute to substantial disability-adjusted life years (DALYs) lost, further exacerbating the socioeconomic impact in endemic regions.

Community-based screening plays a crucial role in mitigating the burden of RHD by enabling early detection and timely intervention to prevent disease progression [4]. Traditional screening methods,

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such as auscultation, have shown limited sensitivity and depend heavily on trained physicians [5]. In contrast, echocardiography has emerged as the gold standard for RHD diagnosis due to its superior sensitivity and specificity. However, its widespread use is hindered by high costs, reliance on expert operators, and limited accessibility in endemic regions [6, 7]. To overcome these barriers, simplified echocardiography protocols have been developed to facilitate large-scale screening by nonexpert operators while maintaining diagnostic accuracy. The World Heart Federation's 2023 guidelines now support simplified screening criteria, further strengthening the role of nonexpert-led initiatives in RHD detection [8].

Simplified echocardiography provides a streamlined approach to RHD screening by focusing on key echocardiographic features such as mitral valve motion and valvular regurgitation [7]. Unlike conventional echocardiography, which requires extensive training, simplified protocols can be implemented following brief, standardized training programs, enabling task-sharing among healthcare workers [8]. Studies have demonstrated that simplified echocardiography effectively identifies high-risk individuals and predicts disease progression. A scoring system based on the World Heart Federation (WHF) criteria has been shown to accurately stratify risk, supporting its role in guiding clinical decision-making and secondary prophylaxis [9, 10].

The feasibility of simplified echocardiography has been further enhanced by technological advancements, particularly in portable and handheld ultrasound devices, making screening accessible even in remote areas [7]. A study by Johannsen, et al. [11] highlighted that a single-view echocardiographic screening protocol significantly improved efficiency while maintaining diagnostic accuracy [11]. Although simplified echocardiography may have slightly lower specificity than full diagnostic echocardiography, it remains an effective preliminary screening tool, allowing for early identification of suspected cases and timely confirmatory testing [8].

Despite its promise, the use of nonexpert operators in echocardiographic screening presents challenges related to image acquisition quality, diagnostic accuracy, and interobserver variability. Studies have demonstrated that briefly trained healthcare workers can achieve acceptable image quality and diagnostic agreement with expert cardiologists when using focused cardiac ultrasound [12]. Given the potential impact of simplified echocardiography in expanding access to RHD screening, this systematic review and meta-analysis aim to evaluate the effectiveness of nonexpert-operated echocardiography in community screening programs and its potential to enhance early detection and management of RHD in high-burden settings.

2. Methods

2.1. Search Strategies

We retrieved all available studies from PubMed, Web of Science (WoS), Scopus, ProQuest, and ScienceDirect published in the last 10 years and limited to English-language articles. The keywords used for the literature search strategy applied Boolean operators and was customized for each database. The specific search queries included "((community screening) OR (mass screening) OR (pediatric population) OR (endemic areas) OR (high-risk groups) OR (active case finding)) AND ((echocardiography) OR (transthoracic echocardiography) OR (portable echocardiography)) AND ((rheumatic heart disease) OR (RHD) OR (subclinical rheumatic heart disease)) AND ((nonexpert) OR (non-physician) OR (simplified screening protocol) OR (task shifting) OR (task sharing) OR (focused cardiac ultrasound) OR (FCU) OR (FoCUS) OR (POCUS) OR (Single Parasternal-Long-Axis-View-Sweep Screening Echocardiographic Protocol) OR (SPLASH) OR (single-view screening))" for PubMed, WoS, and Scopus, while "(echocardiography) AND ((community screening) OR (simplified screening protocol) OR (task shifting) OR (focused cardiac ultrasound) OR (nonexpert)) AND (rheumatic heart disease)" was used for ProQuest and ScienceDirect. The references of the included studies were also manually searched to identify additional relevant articles.

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This systematic review was prepared according to the Preferred Reporting Items for a Systematic Review and Meta-Analysis (PRISMA) guidelines [13]. The protocol for this review is registered with the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number [PROSPERO belum didaftarkan].

2.2. Study Selection

The screening of articles was independently conducted by three [mohon diganti sesuai jumlah author] reviewers. Any disagreements were resolved through discussion, and if necessary, a third reviewer was consulted to reach a consensus. Studies were selected based on predefined inclusion and exclusion criteria.

The inclusion criteria were as follows: (1) studies evaluating the use of echocardiography by nonexpert operators for rheumatic heart disease (RHD) screening; (2) observational studies (cohort, cross-sectional, or case-control) or diagnostic accuracy studies comparing results with a reference standard; and (3) studies reporting data suitable for meta-analysis, such as true positive (TP), false positive (FP), true negative (TN), false negative (FN), sensitivity, or specificity values.

The exclusion criteria were as follows: (1) studies in which echocardiography was performed exclusively by cardiologists or expert operators; (2) studies that did not evaluate the accuracy or implementation of screening protocols; and (3) studies based on predictive modeling without primary data.

2.3. Quality Assessment

The methodological quality of the included studies was evaluated using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool [14] which assesses the risk of bias and applicability concerns in diagnostic studies. This tool examines four key domains: patient selection, index test, reference standard, and flow and timing. Each item in these domains was rated as "yes," "no," or "unclear." If all responses in a domain were "yes," the study was considered low risk for that domain. If all responses were "no," it was classified as high risk, while mixed responses resulted in an unclear risk rating. Two reviewers independently conducted the quality assessment, and any disagreements were resolved through discussion. If consensus was not reached, a third reviewer was consulted.

2.4. Data Extraction

Data from the included studies were extracted by one reviewer following a predefined table format, with a second reviewer verifying the extracted data. The extracted information included: (1) basic study details such as title, authors, and publication year; (2) participant characteristics, including age, gender, sample size, and study setting; and (3) diagnostic study details, including true positive (TP), false positive (FP), true negative (TN), and false negative (FN) values, along with other study-specific variables related to population, reference and index tests, and test outcomes. Any discrepancies during the data extraction process were resolved through discussion, with the involvement of a third reviewer when necessary. The extracted data were utilized for both quality assessment and evidence synthesis.

2.5. Statistical Analysis

Heterogeneity among the included studies was assessed using Stata 17.0, considering both threshold and non-threshold effects. Threshold effects arise from variations in cut-off values, whereas non-threshold effects stem from factors such as differences in diagnostic criteria, study designs, or operator expertise. If substantial heterogeneity was detected, a random-effects model was applied for meta-analysis. Conversely, if heterogeneity was minimal, a fixed-effects model was used. Since this meta-analysis focused on studies with a uniform cut-off score, threshold effects were not a concern, and only non-threshold heterogeneity was analyzed. The meta-analysis was performed using a Bivariate Random-effects Meta-Analysis (BRMA) model (Reitsma et al., 2005), generating pooled estimates of

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sensitivity, specificity, summary receiver operating characteristic (SROC) curves, and area under the curve (AUC) values with 95% confidence intervals (CIs). Additionally, risk of bias and applicability concern figures were generated using Review Manager 5.3.

3. Result

3.1. Selection Process

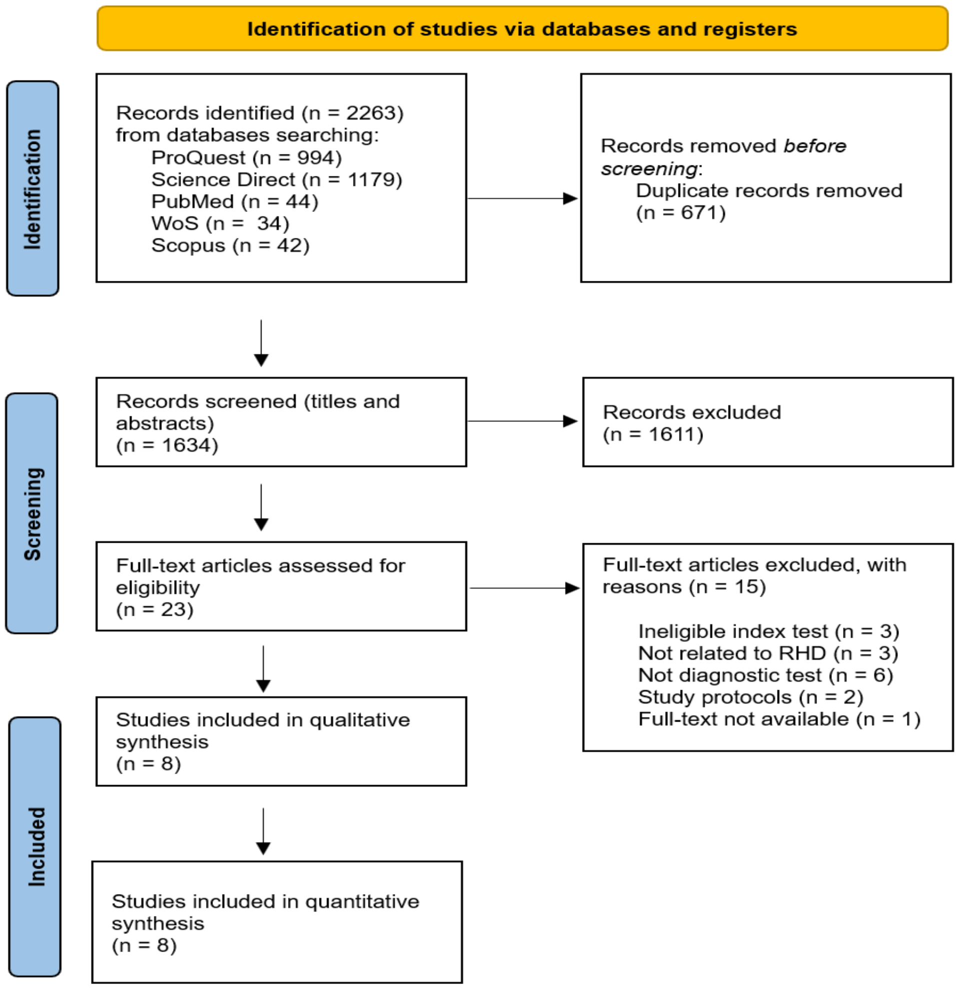

Figure 1.
Preferred Reporting Items for a Systematic Review and Meta- Analysis (PRISMA) flow diagram illustrating study identification, selection, eligibility and inclusion.

The literature search results are presented following the PRISMA guidelines [13] with the study selection process illustrated in Figure 1. A comprehensive search across multiple databases initially identified 2,263 records. Before the screening process, 671 duplicate records were removed. The remaining 1,634 records underwent title and abstract screening, resulting in the exclusion of 1,611 records. Subsequently, 23 full-text articles were reviewed for eligibility, of which 15 were excluded due to various reasons: ineligible index tests (n = 3), lack of relevance to RHD (n = 3), not being a diagnostic test (n = 6), study protocols (n = 2), and unavailability of the full text (n = 1). Eight studies met the predefined inclusion criteria and were incorporated into both the qualitative and quantitative synthesis of this review.

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Table 1.
Characteristic of Selected Studies.

Author & year	Operator	Overview of Training	Previous Experience in Echocardiography	Type of Echocardiography	Axis	Screening positive cut-off criteria	Sample size (N)	% Female	Age (range)
Beaton, et al. [15]	2 nurses, 2 medical students, 2 biomedical	3w self-directed program followed by field testing in school-based screening without hands-on or supervised training.	6w – 1y of practical imaging experience.	Interpretation-only study; no image acquisition by nonexpert operators.	NR	MR ≥ 1.5 cm or any AR MR ≥ 2 cm or any AR	397	49.10%	5–18 y
Engelman, et al. [12]	8 nurses	1w classroom-based workshops followed by 7w of supervised practical training.	No prior experience.	FOCUS protocol (12-step simplified) using M-Turbo portable ultrasound.	parasternal long axis, parasternal short axis, and apical views	Any MR or any AR MR ≥ 1 cm or any AR MR ≥ 1.5 cm or any AR MR ≥ 2 cm or any AR	2004	51.40%	5–15 y
Francis, et al. [16]	10 non specialist doctors, 6 nurses, 6 community health workers	Online RHD modules (multilingual), followed by a 10d face-to-face course (lectures, ≥100 supervised SPLASH studies).	4/18 practitioners had prior screening experience	SPLASH (single parasternal long-axis sweep) using Philips Lumify.	single parasternal long axis	Any MR or any AR MR ≥ 0.5 cm or any AR MR ≥ 1 cm or any AR MR ≥ 1.5 cm or any AR MR ≥ 2 cm or any AR	133		5–20 y
Mirabel, et al. [17]	2 nurses	3d of lectures followed by 30h of hands-on training with normal and RHD patients.	No prior experience.	Focused Cardiac Ultrasound (FCU) approach using Vscan (GE system).	parasternal long axis and parasternal short axis, apical 4-, 2-, and 3-chamber views	MR ≥ 2 cm or any AR	1217	51.40%	9–10 y
Sanyahumbi, et al. [18]	8 clinical officer on bachelor's degree programme	3.5d of lectures followed by 2d of mentored field screening (~60 echocardiographic scans)	NR	Portable echocardiography machine with S5-1 transducer probe (Philips).	NR	MR ≥ 1.5 cm or any AR	20	NR	5–16 y
Voleti, et al. [19]	2 nurses, 2 physicians, 1 medical student, 1 patient care technician	Online RHD modules, quiz, two hands-on sessions (1.5h each) + 2d practical training	NR	Handheld echocardiography (HHE) using Vscan (GE system).	NR	MR ≥ 1.5 cm or any AR	632	49%	6–15 y
Ploutz, et al. [20]	2 nurses	4h physician-led modules followed by 2d hands-on session (≥50 supervised studies).	6m of experience in limited echocardiography	Handheld echocardiography (HHE) using Vscan	parasternal long axis and apical four chamber and five-	MR ≥ 1.5 cm or any AR	956	57.90%	5–17 y

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				(GE system).	chamber views				
Diamantino, et al. [21]	2 biomedical technicians 1 nurse	Computerized curriculum (WiRED, Portuguese) followed by field training with a cardiologist (duration not specified)	12–18m of practical experience.	Interpretation-only study; no image acquisition by nonexpert operators.	NR	MR ≥ 1.5 cm or any AR	587	NR	7–1 y

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3.2. Characteristic of Selected Studies

The studies involved various types of nonexpert operators, including nurses, medical students, biomedical technicians, community health workers, and non-specialist doctors, with varying levels of prior echocardiography experience. Training duration and formats varied across studies, ranging from brief online modules and classroom-based workshops to extensive supervised hands-on practice in field settings. The baseline characteristics of the included studies are shown in Table 2.

Image acquisition was conducted in most studies, except for two, which were interpretation-only studies with no imaging performed by nonexpert operators. The echocardiographic views assessed included parasternal long-axis, short-axis, and apical views. Screening criteria for positive RHD findings varied slightly, with most studies defining a positive case as the presence of mitral regurgitation (MR) ≥ 1.5 cm or any degree of aortic regurgitation (AR), though some included additional thresholds.

3.3. Risk of Bias and Applicability Concerns

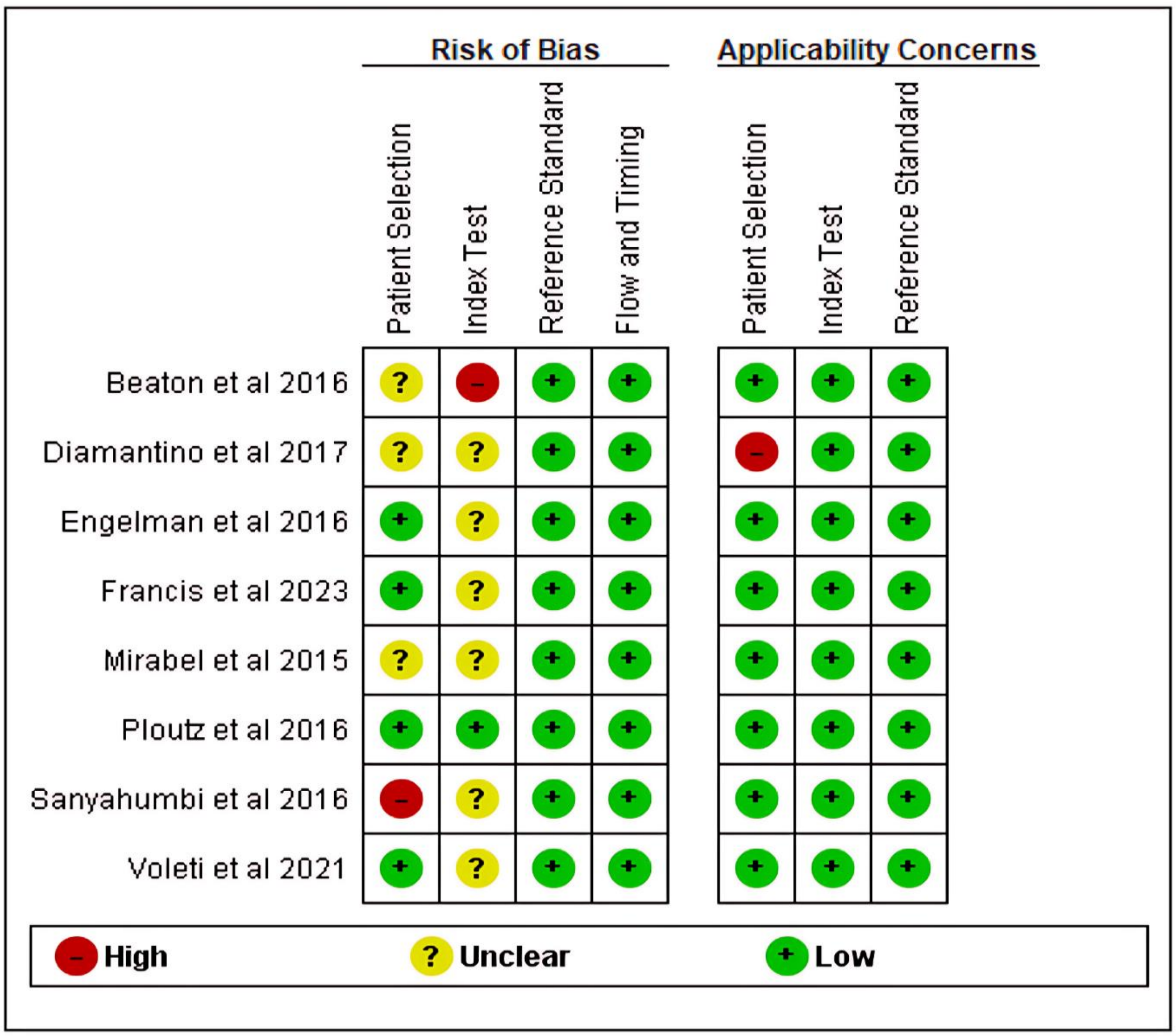

Figure 2.
Quality assessment of each selected study.

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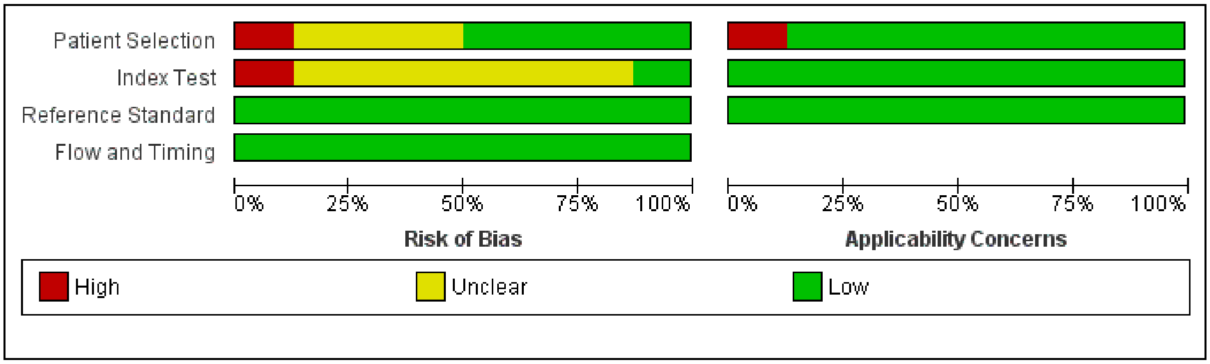

Figure 3.
Quality assessment of all selected studies.

Among the eight selected studies, all exhibited low applicability concerns across patient selection, index test, and reference standard domains. However, variations were observed in the risk of bias assessment. One study demonstrated a high risk in the index test domain, while the remaining studies had either low or unclear risk in different domains. Several studies had an unclear risk of bias in patient selection, indicating potential limitations in study design or participant recruitment. Despite these concerns, most studies maintained a low risk of bias in the reference standard and flow and timing domains, suggesting overall methodological reliability. The detailed risk of bias and applicability concerns for each study are illustrated in Figure 2, while the aggregated quality assessment of all selected studies is summarized in Figure 3.

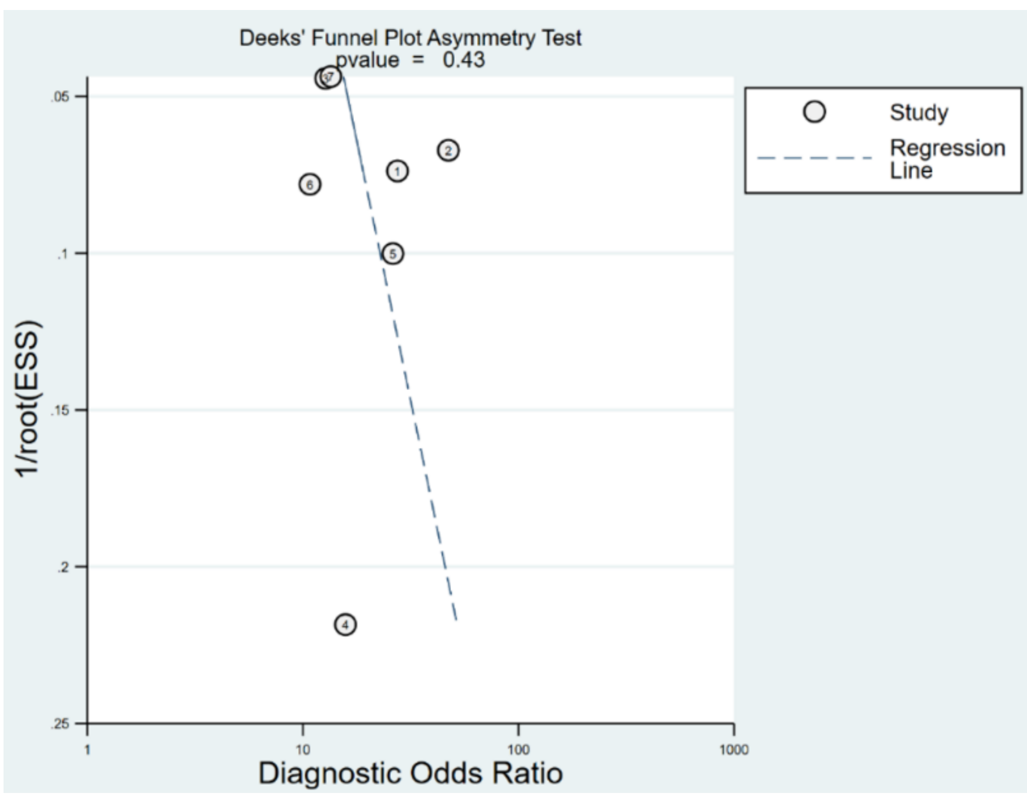

Figure 4.
Deeks' funnel plot asymmetry test.

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3.4. Risk of Publication Bias

The risk of publication bias was assessed when the cut-off was MR ≥ 1.5 cm or any AR. According to the results of Deeks' funnel plot asymmetry test in Figure 4 (p = 0.43 [>0.1]), there was no risk of publication bias. The distribution of studies appears relatively symmetrical, indicating that the meta-analysis results are more valid and not influenced by publication selectivity. Furthermore, this meta-analysis is more reliable as it is not affected by the absence of studies with negative or low-significance results.

3.5. Test for Heterogenity

Table 2.
Heterogenity test for different cut off.

Cut-off score for Screening criteria	Number of studies	Cochran-Q	P	I^2
MR ≥ 1.5 cm or any AR	7	48.10	0.000	96.00%
MR ≥ 2 cm or any AR	4	23.49	0.000	91.00%

The analysis showed that when the cut-off was MR ≥ 1.5 cm or any AR, the Cochran-Q test yielded $P < 0.05$ and $I^2 = 96\%$, indicating substantial heterogeneity. Due to the very high I^2 value, a random-effects model should be used. The threshold effect was 41%, which, although relatively high, was still below 50%, suggesting that most of the heterogeneity stemmed from factors other than threshold effects (e.g., differences in study design, patient characteristics, or measurement tools).

When the cut-off was MR ≥ 2 cm or any AR, the Cochran-Q test also yielded $P < 0.05$ with $I^2 = 91\%$, indicating high heterogeneity. However, the threshold effect was only 22%, implying that the heterogeneity was primarily driven by factors other than threshold effects. The results of the heterogeneity test are shown in Table 2.

3.6. Meta-Analysis of Different Cut-Off Values

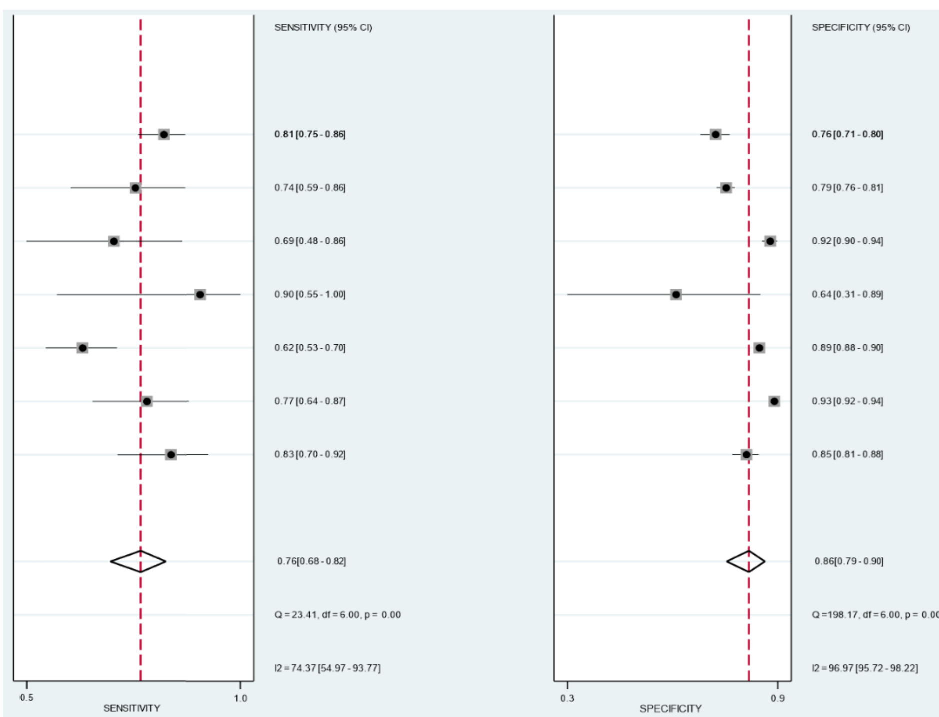

Figure 5.
Sensitivity and specificity of cut-off MR ≥ 1.5 cm or any AR.

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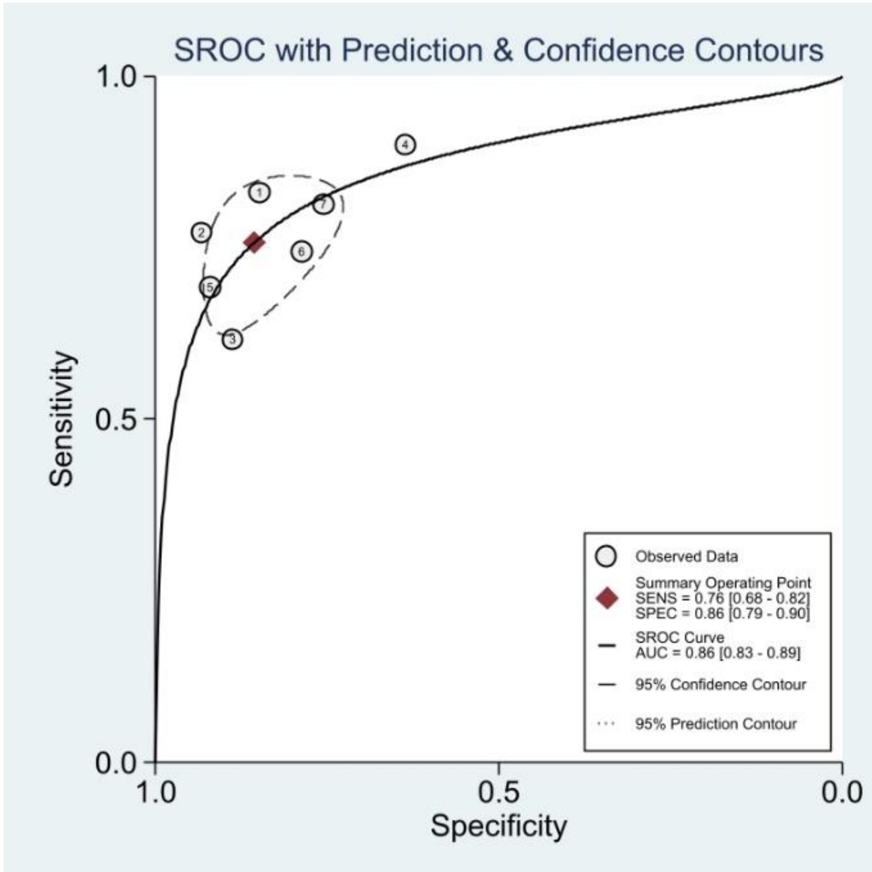

Figure 6.
SROC of cut-off MR ≥ 1.5 cm or any AR.

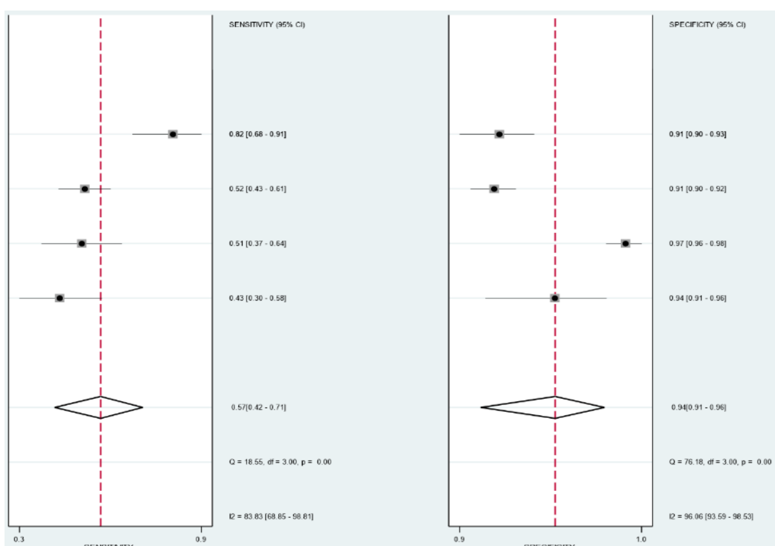

Figure 7.
Sensitivity and specificity of cut-off MR ≥ 2 cm or any AR.

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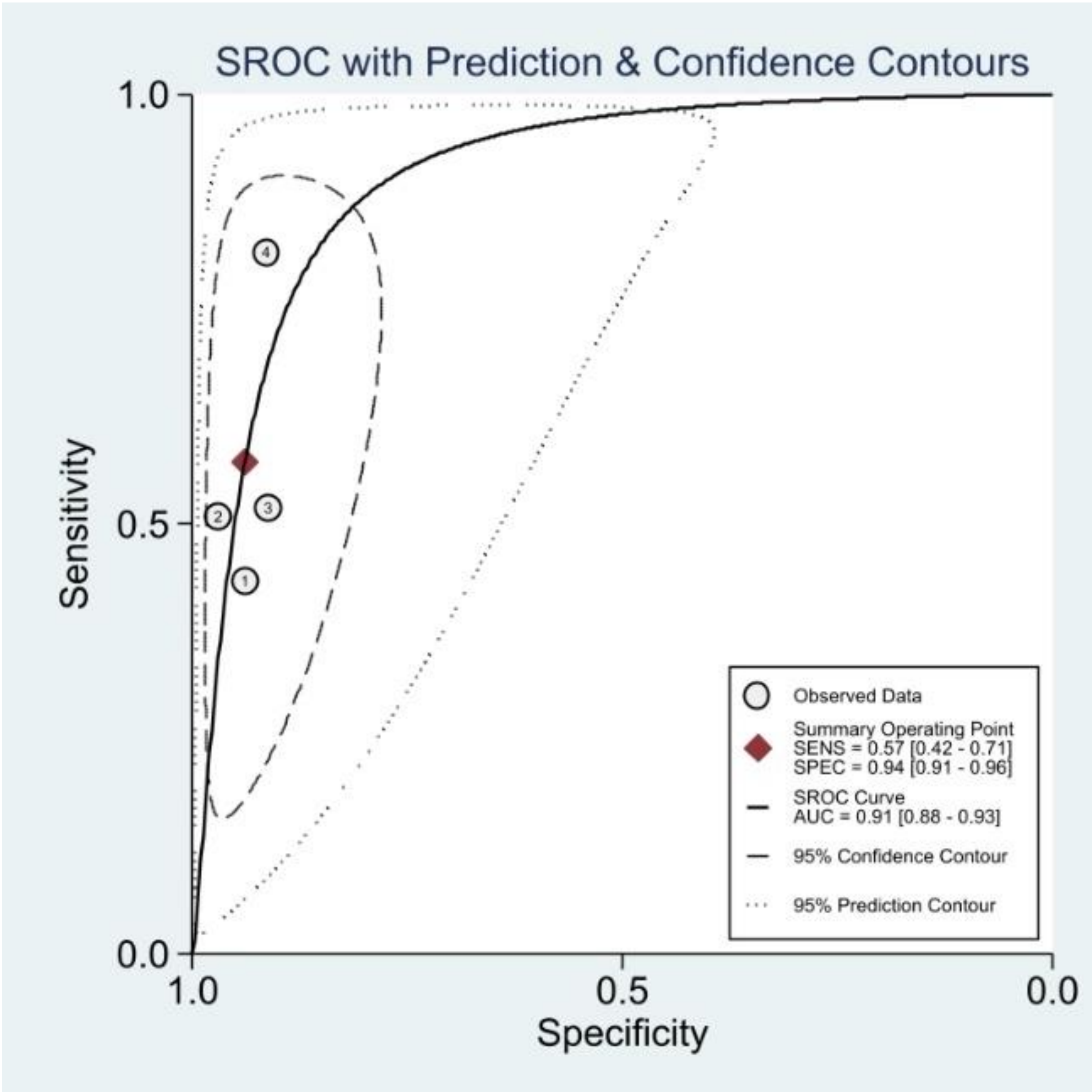

Figure 8.
SROC of cut-off MR ≥ 2 cm or any AR.

This meta-analysis evaluated the diagnostic performance of two different cut-off values for detecting rheumatic heart disease (RHD) using echocardiography performed by non-expert operators. The two thresholds analyzed were MR ≥ 1.5 cm or the presence of AR (Figure 5 and Figure 6) and MR ≥ 2 cm or the presence of AR (Figure 7 and Figure 8).

For the MR ≥ 1.5 cm or any AR threshold, the pooled sensitivity was 0.76 (95% CI: 0.63–0.82), while the pooled specificity was 0.86 (95% CI: 0.79–0.90). The summary receiver operating characteristic (SROC) curve demonstrated an area under the curve (AUC) of 0.88 (95% CI: 0.83–0.89). Conversely, for the MR ≥ 2 cm or any AR threshold, the pooled sensitivity decreased to 0.57 (95% CI: 0.42–0.71), while specificity remained high at 0.94 (95% CI: 0.91–0.96). The SROC analysis yielded an AUC of 0.91 (95% CI: 0.88–0.93).

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4. Discussion

This meta-analysis demonstrates that simplified echocardiography, when performed by nonexpert operators, achieves a pooled sensitivity of 0.76 (95% CI: 0.63–0.82) and specificity of 0.86 (95% CI: 0.79–0.90) at the MR ≥ 1.5 cm or any AR threshold. These findings highlight its potential as a viable screening tool in resource-limited settings, where expert-performed echocardiography remains inaccessible. However, substantial heterogeneity (I^2 = 96%) suggests variability in operator training, imaging protocols, and diagnostic criteria. Despite these variations, the observed diagnostic performance supports the integration of simplified echocardiography into community-based RHD screening programs.

Adjusting the screening threshold revealed a trade-off between sensitivity and specificity. The MR ≥ 2 cm or any AR cutoff increased specificity to 0.94 (95% CI: 0.91–0.96) but reduced sensitivity to 0.57 (95% CI: 0.42–0.71), increasing diagnostic certainty at the cost of missed cases. In contrast, the MR ≥ 1.5 cm or any AR threshold provided higher sensitivity, enhancing early case detection but with a greater risk of false positives. These emphasize the need to tailor screening criteria based on program objectives—maximizing case detection in large-scale screening versus ensuring diagnostic accuracy in confirmatory assessments.

A notable comparison can be drawn with the study by Nascimento, et al. [9] which evaluated echocardiographic screening conducted by nonphysicians in pregnant women, integrating remote expert interpretation. In their study, 20 healthcare workers utilized handheld echocardiography in primary care centres, identifying suspected RHD in 3.2% of cases, with mitral valve involvement being the predominant finding. Among screen-positive individuals who underwent confirmatory echocardiography, 80.4% had major heart disease, reinforcing the potential of simplified protocols in early disease detection [9].

The implementation of simplified echocardiography as a screening tool for rheumatic heart disease (RHD) in resource-limited settings offers several notable advantages. First, it significantly enhances access to cardiac screening in underserved regions by utilizing handheld ultrasound devices and task-sharing models, enabling nonexpert operators to conduct initial assessments. With adequate training and adjunctive technology, nonexpert screeners can achieve reasonable sensitivity and specificity in detecting RHD. Despite these advantages, simplified echocardiography presents several challenges that must be addressed to optimize its clinical utility. A primary limitation is its tendency to overestimate the prevalence of RHD, particularly in the assessment of valvular regurgitation, leading to potential misclassification of normal or borderline cases [22]. Overestimation is most commonly observed in mitral regurgitation and left ventricular dysfunction assessments, contributing to discrepancies between screening and standard echocardiographic findings [23]. Additionally, operator variability remains a critical factor, as novice screeners may initially underperform compared to experienced counterparts, with sensitivity improving only after extensive training [19]. However, this finding contrasts with Beaton, et al. [15] who reported no notable differences in screening accuracy based on the type of user or duration of experience [15].

The integration of simplified echocardiography into national screening programs for rheumatic heart disease (RHD) holds significant potential for endemic regions. Diamantino, et al. [24] demonstrated that the addition of a simplified 7-view echocardiographic screening, performed by non-physicians using handheld devices, significantly improved the performance of a clinical prioritization tool for primary care referrals. It emphasizes the value of handheld echocardiography in improving resource utilization by directing high-risk patients to comprehensive diagnostic services, thereby reducing unnecessary referrals and optimizing healthcare expenditures Diamantino, et al. [24]. Abrokwa, et al. [25] further supported this task-shifting model, noting that point-of-care ultrasound (POCUS) performed by non-expert healthcare providers in low-resource settings led to accurate diagnoses across multiple conditions, including cardiac abnormalities [25].

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A critical component for successful implementation is ensuring standardized training and competency validation for non-expert operators. Beaton, et al. [15] evaluated the efficacy of a computer-based training (CBT) curriculum for teaching RHD echocardiographic interpretation to non-experts and found that participants achieved a sensitivity of 83% and specificity of 85% for detecting RHD using handheld echocardiography. The asynchronous, self-directed CBT modules, which included interactive quizzes and real case image reviews, provided a scalable and cost-effective training solution adaptable for widespread use in low-resource settings Beaton, et al. [15]. Abrokwa, et al. [25] also highlighted that standardized curriculum, combined with quality assurance mechanisms such as certification and remote tele-supervision, are crucial for ensuring diagnostic accuracy and maintaining service quality when employing non-expert providers [25].

This meta-analysis is subject to several limitations, primarily stemming from the heterogeneity among included studies. Variability in operator training, echocardiographic protocols, operator experience, and screening thresholds contributed to significant methodological differences. These variations may have influenced the pooled estimates. Another key limitation is the potential risk of bias in sample selection and reference standards. Some studies employed selective recruitment strategies, such as Mirabel, et al. [17] and Beaton, et al. [15] relied on nonexpert operators for initial screenings, followed by expert confirmation, which may introduce classification bias that could affect the representativeness of screened populations. Given these limitations, further longitudinal evaluations are needed to assess the real-world effectiveness of community-based RHD screening using simplified echocardiography, particularly its impact on morbidity and mortality [15, 17].

5. Conclusion

This meta-analysis supports the feasibility of simplified echocardiography performed by nonexpert as a scalable strategy for RHD screening in endemic regions. The pooled sensitivity and specificity values suggest that this approach can facilitate early detection, particularly in resource-limited settings where expert-performed echocardiography remains inaccessible. While variations in training duration, imaging protocols, and diagnostic criteria contribute to heterogeneity, the overall diagnostic accuracy supports the integration of simplified echocardiography into large-scale screening programs. The findings highlight the potential of task-sharing models in expanding access to cardiac care and reducing the burden of RHD.

However, challenges remain in optimizing operator training, ensuring image acquisition quality, and minimizing false positives. Adjusting screening thresholds may balance sensitivity and specificity, allowing tailored strategies for different screening objectives. Further studies are needed to evaluate the long-term impact of simplified echocardiography on patient outcomes, including its role in guiding secondary prophylaxis and reducing RHD-related morbidity. Standardized training programs, competency validation, and remote expert supervision will be essential in maximizing the utility of nonexpert-operated echocardiography in endemic regions.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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