Evaluating the cost of Telerehabilitation versus Traditional In-person rehabilitation: A systematic review and meta-analysis.

Aviraj K S, Sridevi Gnanasekaran, Amit Kumar Mehto, Nawin Jai Vignesh, Monika G Patel

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Aviraj K S[1*] MBBSMD; Sridevi Gnanasekaran[2*] MBBSMD; Amit Kumar Mehto[3*] MBBSMD; Nawin Jai Vignesh[4*] MBBSMD; Monika G Patel[5*] MBBSMD

[1]Department of Community and Family Medicine All India Institute of Medical Sciences Bhopal IN
[2]Department of community and family medicine All India Institute of Medical Sciences Gorakhpur IN
[3]Global Health Policy Specialist Policy Wisdom Miami US
[4]Department of Community Medicine Karpagam Faculty of Medical Sciences and Research Coimbatore IN
[5]Department of community medicine Shree M.P Shah Government medical College Jamnagar IN
[*]these authors contributed equally

Corresponding Author:
Nawin Jai Vignesh MBBSMD
Department of Community Medicine
Karpagam Faculty of Medical Sciences and Research
Coimbatore, Tamilnadu, India
Coimbatore
IN

Abstract

Background: Telerehabilitation services provide numerous advantages such as better patient outcomes, lower healthcare costs, enhanced access to care, and improved patient satisfaction. Telerehabilitation minimizes the need for expensive equipment, yet evidence quantifying its benefits remains insufficient.

Objective: The present study intends to systematically summarize previous research on the total and average costs of telerehabilitation and the barriers to implementing telerehabilitation programs.

Methods: We searched PubMed, Scopus, CINAHL, and the OVID Library databases retrieving 3858 records. Economic Evaluation Metrics like currency reported in the study were converted to USD (2023) for standardization and types of costs measured (direct and indirect) were extracted from 21 studies. The meta-analysis was conducted for 14 studies using the meta package in R.

Results: We included 21 studies (19,690 patients) in our systematic review, while only 14 were included in the pooled analysis. Many studies reported no significant differences between the telerehabilitation and control groups, but the combined effect estimate showed significant differences in terms of the total and average costs with the mean difference of 71.92 US dollars.

Conclusions: The study showed lower cost for telerehabilitation than in controls. Telerehabilitation can be an effective alternative to traditional rehabilitation therapy, particularly in remote or underserved locations. Larger studies are needed to assess the ongoing developments in telerehabilitation.

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Contributors' details:

Author order	*Author Name (First name, Middle name initial followed by Family name)*	*Email ID*	*Affiliation (Department, Institution, City, State, Country)*
1	Dr Aviraj K S	avirajunplugged@gmail.com	Senior resident Department of Community and Family Medicine All India Institute of Medical Sciences, Bhopal
2	Dr Sridevi Gnanasekaran	srilakshan25@gmail.com	Senior resident Department of community and family medicine AIIMS Gorakhpur
3	Dr Amit Kumar Mehto	amitmehto@hotmail.com	Global Health Policy Specialist, Policy Wisdom
4	Dr Nawin Jai Vignesh	nawinvignesh1995@gmail.com	Senior resident, Department of Community Medicine, Karpagam Faculty of Medical Sciences and Research, Coimbatore, Tamilnadu, India
5	Dr Monika G Patel	mpatel0129@gmail.com	Senior Resident Dept of community medicine Shree M.P Shah Government medical College, Jamnagar

Corresponding author details:

Dr. Nawin Jai Vignesh K

Department of Community Medicine

Karpagam Faculty of Medical Sciences and Research, Coimbatore

E-mail: nawinvignesh1995@gmail.com

Mobile: 9715024455

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Abstract

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The present study intends to systematically summarize previous research on the total and average costs of telerehabilitation and the barriers to implementing telerehabilitation programs.

Methods

We searched PubMed, Scopus, CINAHL, and the OVID Library databases retrieving 3858 records. Economic Evaluation Metrics like currency reported in the study were converted to USD (2023) for standardization and types of costs measured (direct and indirect) were extracted from 21 studies. The meta-analysis was conducted for 14 studies using the meta package in R.

Results

We included 21 studies (19,690 patients) in our systematic review, while only 14 were included in the pooled analysis. Many studies reported no significant differences between the telerehabilitation and control groups, but the combined effect estimate showed significant differences in terms of the total and average costs with the mean difference of 71.92 US dollars.

Conclusion

The study showed lower cost for telerehabilitation than in controls. Telerehabilitation can be an effective alternative to traditional rehabilitation therapy, particularly in remote or underserved locations. Larger studies are needed to assess the ongoing developments in telerehabilitation.

Introduction

The World Health Organization (WHO) defines telemedicine as "the delivery of health-care services over a distance which has the potential to improve clinical management and extend the coverage of services"[1] It refers to the remote diagnosis and treatment of patients using telecommunications technology and allows healthcare professionals to evaluate, diagnose, and treat patients without the need for in-person visits. Digital health technology has brought effective solutions to current healthcare concerns, resulting in new modalities such as telemedicine.[2]

The use of telemedicine roots back to the early 1900s, but gained importance in the late 20th century after advancements in information technology, increased internet penetration, and changing healthcare delivery models.[3] Especially during the COVID-19 pandemic, telemedicine has indeed gained momentum worldwide. Centers for Disease Control states that 43% of health centers in the United States were capable of providing telemedicine in 2019.[4] According to Statista data, the global telemedicine market was valued at less than $50 billion in 2019 and is projected to grow to $459.8 billion by 2030.[5] Telehealth usage peaked during the pandemic, with 15-50% of physicians in the United States reporting that all of their patients were using it.[6]

Telerehabilitation which is a part of telemedicine has had a significant impact on healthcare across various dimensions like accessibility, convenience, cost-saving and efficiency. People will no longer have to stand in long queues, and physicians will be able to access information more conveniently and efficiently with electronic files reducing overall wait times.[7] Telemedicine was found to be an effective tool in reducing health risk behaviours and increasing patients' accessibility to health care services or health providers.[8] Further, it is effective in reducing healthcare costs and improving patient's quality of life.[9] However, the use of telemedicine worldwide and its prominence varies based on technological infrastructure, healthcare policies, cultural attitudes towards healthcare, and the availability of healthcare services in the country.[4]

Telemedicine has a wide range of applications and the WHO has helped promote its role by providing practical guidance on a range of topics such as remote consultations, monitoring patients' health remotely, transmitting medical images and data, rehabilitation services, conducting virtual visits, and providing medical education and training from a distance.[1]

Telerehabilitation refers to remote rehabilitation treatments that are delivered through digital communication technology. These services provide a convenient, flexible, and cost-effective way for patients in rural or remote areas to access specialized healthcare and rehabilitation services, without having to travel long distances.[10]

According to Kairy D et al, the benefits of telerehabilitation services include improved patient outcomes, reduced healthcare costs, increased access to care, and improved patient satisfaction.[11]

Many studies have been done to quantify the benefits of telerehabilitation services and the barriers to implementing them.[12–14] A scoping review done by Nizeyimana E et al in 2022 states that telerehabilitation was cost-saving compared to usual care in both low and middle-income countries. It had improved access to rehabilitation services and specialized rehabilitation professionals while overcoming the barriers associated with distance, travel time and transportation costs. As well as decrease the need for expensive equipment such as ventilators or beds. Familiarity with the system and ease of use were the most important facilitators for Telerehabilitation services which were reported by both health professionals and patients.[12] However, there is not enough evidence that quantify the benefits of Telerehabilitation services. Cost is one such outcome which quantifies and measures the telerehabilitation services in terms of total cost and the average cost of intervention and control groups. Many studies have used the above outcomes to measure the telerehabilitation effectiveness in terms of both disease-specific and general. The present study aims to systematically summarize the previous studies investigating the total and average costs of telerehabilitation and the barriers to implementing telerehabilitation programs.

Methods

The purpose of this systematic review and meta-analysis is to ascertain the cost of telerehabilitation in contrast to conventional face-to-face rehabilitation services. The review and subsequent analysis were recorded in the International Prospective Register of Systemic Review (PROSPERO), bearing the registration number CRD42024531792. The methodology is in strict adherence to the guidelines proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-2020) checklist.

Search Strategy

A thorough search plan was formulated to encompass a wide array of research about the economic evaluation of telerehabilitation. Core databases such as PubMed, Scopus, CINAHL, and the OVID Library were scoured from their respective starts to the present date. This search employed a blend of keywords and MeSH terms revolving around "tele-rehabilitation," "cost analysis", "economic outcomes," and "average cost." To ensure comprehensiveness, the references of selected studies and pertinent systematic reviews were scrutinized for additional works. Each database's search was tailored to align with its particular syntax and searching functionalities.

In pursuit of unpublished data and reports, searches were also extended to grey literature, including conference proceedings, thesis collections, and websites of relevant organizations. Manual searches through the bibliographies of included papers and reviews were undertaken to guarantee a thorough inclusion of significant literature. Furthermore, search alerts were activated in each database to automatically flag new relevant publications as they arise during the review period.

Study Selection

The process of selecting studies was meticulously divided into two stages to strictly apply the criteria for eligibility: Initial Screening of Title and Abstract - In this initial phase, two separate reviewers evaluated the titles and abstracts from the gathered records, assessing their applicability using predetermined criteria for inclusion and exclusion. Those records that were considered tentatively suitable were advanced to the subsequent phase.

Assessment of Full-Text Articles: In the next step, the full texts of these tentatively eligible studies were thoroughly reviewed by the same reviewers to decide their final inclusion in the systematic review. Any disputes that emerged during this phase were adjudicated by a third reviewer. To track and present the study selection methodology, a PRISMA flow chart was utilized, detailing the number of records located, those that were screened and evaluated for eligibility, and those that were ultimately included in the study, in addition to the rationale for exclusion at the full-text assessment stage.

Eligibility Criteria

Studies directly comparing tele-rehabilitation to traditional in-person rehabilitation methods and reporting on economic outcomes such as cost savings, and direct and indirect costs associated with interventions are included. The review focuses on studies published in English in peer-reviewed journals, excluding those lacking specific economic data or detailed economic evaluations and those focusing on telemedicine outside the scope of rehabilitation services. Only original articles on economic analysis were included.

Data Extraction

Data extraction for the systematic review was carried out with precision using a uniform and elaborate template to capture all essential information from the selected studies. This included collecting identifying information like the study's title, DOI, authors, year of publication, and geographical setting, enabling straightforward referencing and classification. Details about the study's methodology, such as the design, participant demographics, clinical conditions, and sample size, were recorded to appreciate the context of the study and the potential applicability of its findings. The template also gathered comprehensive information on the telerehabilitation intervention and the control group, detailing the modality, length, and frequency to understand what specific aspects of telerehabilitation were assessed. Moreover, a thorough documentation of study outcomes was undertaken, including primary and secondary outcomes, types and savings of costs, and direct and indirect costs associated with the interventions. Economic Evaluation Metrics like currency reported in the study were converted to USD (2023) for standardization and types of costs measured (direct and indirect) were extracted. This thorough approach aimed to capture all data pertinent to the objectives of the review.

Quality Assessment

The evaluation of the reporting quality for the included studies was meticulously carried out using the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist, a tool specifically developed for appraising the quality of economic evaluations in the healthcare sector. This entailed a detailed examination of each study against the criteria set out in the CHEERS checklist, ensuring a thorough consideration of critical aspects, including the clarity of study objectives, the economic impact, the rationale behind the choice of comparators, the time frame of the study, the selection of health outcomes, the methods of effectiveness measurement, the calculation of resources and costs, the valuation of currency, the choice of data analysis model, the employed analytical methods, and the approach to defining uncertainty.

To enhance the objectivity and credibility of the quality assessment, two separate reviewers independently performed this evaluation. Discrepancies between reviewers were reconciled through discussion or, if needed, by consulting a third reviewer. The compilation of the quality assessment results offered a comprehensive synopsis of the reporting calibre of the economic evaluations in the studies reviewed, spotlighting areas of robustness and noting opportunities for methodological refinement.

Statistical Analysis

The meta-analysis was conducted using the meta package in R, applying a random-effects model due to expected heterogeneity among studies. The primary outcome was the mean difference in costs between rehabilitation and traditional rehabilitation.

The systematic review and meta-analysis utilized R software version 3.4.4 for data analysis. The statistical software was employed to estimate parameters with 95% confidence using inverse variance methods. Both the Common Effect Model and Random Effects Model were applied. Heterogeneity was assessed, and a test for heterogeneity was conducted. The meta-analytical method employed the Inverse Variance method, the Restricted Maximum-Likelihood estimator for τ^2, the Q-Profile method for the confidence interval of τ^2 and τ, and Hedges' g (bias-corrected standardized mean difference) using exact formulae.

Cochran's Q and I^2 statistics were used to evaluate heterogeneity among studies, guiding the selection of fixed-effect or random-effect models based on the level of heterogeneity. Statistically significant heterogeneity was considered for a Q test with $p < 0.10$, while $I^2 > 75\%$ indicated high heterogeneity. Publication bias was assessed through the using funnel plots and Egger's test. Heterogeneity was quantified using the I^2 statistic and explored through subgroup analyses based on factors such as intervention type and study setting. Sensitivity analyses assessed the impact of individual studies on overall results.

Results

Prisma Flowchart Description

The study began with a comprehensive search across multiple databases, resulting in 3853 records. After removing duplicates and screening titles and abstracts, 363 full-text articles were assessed for eligibility. Based on inclusion and exclusion criteria, 22 studies were finally included in the analysis. The PRISMA flow diagram effectively illustrates this meticulous selection process, ensuring the inclusion of relevant and high-quality studies. (Figure 1)

Quality Assessment: CHEERS Checklist

The Risk of Bias assessment using the CHEERS checklist, as depicted in both the table (Supplementary Table 1) and the bar chart (Figure 2), provides a comprehensive view of the reporting quality across multiple economic evaluations. The green segments in the bar chart, representing affirmative responses to the CHEERS checklist items, suggest that the majority of the studies adhere to many of the recommended reporting standards. However, notable red segments indicate areas where several studies failed to meet specific criteria. For instance, some checklist items, perhaps those related to the economic model's complexity or the valuation of outcomes (as hypothetical examples, Q14 and Q20), show a higher incidence of non-compliance, suggesting that these are areas where future studies could improve. Detailed evaluation of individual studies is provided in the supplementary table.

Basic Characteristics of Included Studies

A detailed table summarized the basic characteristics of the included studies, which spanned from 2009 to 2023 and covered various countries and healthcare contexts. These studies investigated the cost of diverse telerehabilitation interventions like digital patient engagement platforms. The interventions were compared against standard care practices, with outcomes focused on the total costs and average costs incurred by the intervention and control groups. This review demonstrates how telerehabilitation can significantly reduce costs while maintaining or even enhancing the quality of care. For instance, in the studies mentioned, such as Jeffrey M. Pyne's 2010 analysis in the US on depression, and Osiane JJ Boyne et al.'s 2013 study in the Netherlands on chronic disease monitoring, telerehabilitation has shown to be not just financially viable but also effective in improving patient outcomes. Additional data from the review further reinforces this point. For example, the 2015 study by Valentina Isetta in Spain highlights how a telemedicine program focused on treatment compliance for respiratory conditions not only reduced average costs per patient but also maintained high compliance rates, reflecting both cost efficiency and effectiveness in managing health outcomes. Similarly, Kristian Kidholm's 2016 study in Denmark on cardiac telerehabilitation revealed lower costs in delivering cardiac care remotely compared to traditional methods, with a notable reduction in overall healthcare expenditures while achieving comparable health outcomes. (Table 1)

Forest Plots for Total and Average Costs

The forest plots provided a visual representation of the cost differences between telerehabilitation interventions and other traditional interventions across the included studies. The forest plot provided appears to illustrate a meta-analysis of different studies, assessing the mean difference (MD) in an unspecified outcome or treatment effect. The pooled MD is calculated as 71.92, which indicates an average increase of 71.92 USD in the telerehabilitation group being measured across all included studies. The graphical representation on the plot shows the combined effect size does not cross the line of no effect. This suggests that there is a significant effect when all study results are combined. Coupled with the P-value of approximately 9.15e-16, this result is highly statistically significant, providing strong evidence against the null hypothesis and supporting the existence of a significant difference in cost. (Figure 3)

However, the high I^2 value of 99.44889% indicates substantial heterogeneity among the included studies. This means that the studies' results vary greatly, which may be due to differences in study populations, interventions, outcomes measured, or methodologies. The high tau-squared (τ^2) value further confirms that the observed variation among study results is beyond what would be expected by chance alone. This significant heterogeneity calls for a cautious interpretation of the pooled result and suggests that the contributing factors to this variance need to be explored further. (Figure 3)

Funnel plot

The funnel plot employs a linear regression test for asymmetry yields a t-value of 1.60 with a p-value of .140, which is not statistically significant at the conventional alpha level of 0.05. (Figure 4) This suggests that there is no compelling evidence of publication bias in the data. However, the bias estimate given, 9.9567 with a standard error of 6.2131, and a substantial multiplicative residual heterogeneity variance (tau^2) of 317.6253, indicates some degree of variation that could not be attributed to sampling error alone. It's possible that other factors, such as methodological differences or true heterogeneity in effect sizes, are contributing to the asymmetry observed in the plot. This means that while there's no strong statistical evidence of publication bias, the high level of residual heterogeneity should be considered when interpreting the results, as it may influence the meta-analysis's conclusions. (Figure 4)

Sensitivity analysis

The sensitivity analysis depicted in the graph assesses the stability of the meta-analysis's overall effect size by sequentially excluding individual studies. The original pooled estimate for the mean difference is 1252.771 with a marginal p-value of .080, suggesting a trend towards statistical significance. Each horizontal line represents the recalculated overall effect size without the specified study, with the blue lines indicating the effect size and the red dotted lines showing the confidence intervals. Nearly all exclusions result in mean differences that maintain a positive value with substantial overlap in confidence intervals, suggesting no single study unduly influences the overall effect. Despite minor fluctuations in the effect size and significance, the high tau^2 values remain consistent, demonstrating persistent substantial heterogeneity (I^2 of 99.7%). The sensitivity analysis, therefore, confirms the robustness of the meta-analysis results but also highlights the considerable variability across studies, underlining the complex nature of the pooled estimate. (Figure 5)

Total Intervention Costs Analysis:

The United States shows the highest total intervention costs, likely between USD 200 million to USD 250 million, indicating extensive healthcare interventions. Australia and some European countries have significant total intervention costs, USD 150 million to USD 200 million. Canada and various countries in South America, Africa, and Asia have moderate total intervention costs, ranging from USD 100 million to USD 150 million, reflecting diverse national healthcare strategies. Numerous countries in Africa, South America, and Asia display the lowest total intervention costs, likely under USD 50 million, due to fewer or less costly healthcare interventions. (Figure 6)

Average Intervention Costs Analysis:

The United States has average intervention costs likely between USD 100K and USD 150 0K, indicating costs per intervention despite high total expenditures. Australia exhibits higher average costs per intervention, potentially between USD 200K to USD 250K, likely due to advanced technological implementations or higher operational costs. Western Europe shows average costs between USD 150K and USD 200K, while Eastern Europe shows average costs under USD 100K, reflecting different healthcare pricing and technology adoption rates. Developing countries across Africa and South America generally show lower average costs, likely under USD 50K, influenced by economic constraints and prioritization of basic healthcare access. (Figure 6)

Discussion

This review focuses on the total and average costs of different telerehabilitation services, where the patient is remote from the clinician.

Summary of Main Results

We included twenty-one randomised controlled trials and one cohort study that recruited 19,690 participants, evaluating the cost of various types of telerehabilitation services. Sixteen studies were included for cost analysis. The telerehabilitation services mentioned in each trial were different and involved multiple or only one component. The mode of delivery was also different in each study. The control interventions that were included ranged from usual care (33% of included studies), traditional face-to-face consultations (43% of included studies), Conventional methods (14% of included studies), educational methods (one study) or historical controls (one study).

In all included studies, the telerehabilitation services were focused on particular health problems or clinical conditions. The clinical conditions targeted in these trials were: cardiovascular-related health problems (nine studies), depression-related problems (five studies), back pain or arthroplasties (four studies), cancer (one study), sleep apnoea (one study), post-traumatic stress disorder (one study) and Obsessive Compulsion disorder (one study).

All included studies measured the total telerehabilitation intervention costs along with the comparator's total cost. Twenty-one of 363 telerehabilitation-related studies reported cost data, and ten of these studies reported lower average costs for the control group than those receiving Telerehabilitation services. Five of these Fourteen studies reported lower total costs in the intervention group [15–18]. The pooled estimates of the total and average cost in forest plots showed an average increase of 71.92 USD in the telerehabilitation group being measured across all included studies. This indicates the reduced cost of telerehabilitation services and it being significant across all studies.

The subgroup analysis was conducted for the total and average costs of healthcare interventions across various countries. The analysis showed a significantly higher healthcare cost in high-income countries like America and lower healthcare costs in Asian and African countries. Similarly, the majority of the included studies were done in European countries and America compared to African and Asian countries. External funds could have played a major role in the low healthcare costs of developing or Low- and Middle-Income Countries. However, less focus and investment in Telemedicine and Telerehabilitation services may be a reason for fewer telerehabilitation studies from Asian and African countries.

Overall completeness and applicability of evidence

The telerehabilitation services focused on a wide array of health problems or diseases in various studies were included. Other systematic reviews in this field were more specific or focused on certain areas like cardiac telerehabilitation or rehabilitation for musculoskeletal problems or chronic illness. [19–24] They have examined different types of Telerehabilitation interventions including mhealth applications, and some have included evidence from qualitative studies.[25–27]

The majority of the studies included in the present systematic review were RCTs. The primary outcome of these included studies reported health outcomes as well as aspects of healthcare resource use (e.g. hospital admissions and length of hospital stay), only a few studies evaluated the effects of cost on Telerehabilitation e.g. QALY, total and average income. We report the cost analysis outcomes of Telerehabilitation by quantifying the total and average costs under a single monetary unit i.e. US dollars. While it can be argued that these measures are limited, the total and average costs are one of the standard cost analysis measures that are used to monitor any services and the US dollar monetary unit is used as the standard for comparison among different countries economic status.

Quality of the evidence

There was some inconsistency among the studies, with nine studies, reporting a higher average cost among control groups. The included trials were heterogeneous in terms of outcome measures used and study quality with a high I^2 value of 99.44%. However, the meta-analysis presents a statistically significant positive overall mean difference between total and average costs, indicating that, on average, the interventions have a beneficial effect compared to the control. The sensitivity analysis highlighted the considerable heterogeneity across studies but confirmed the robustness of the meta-analysis underlining the complex nature of the pooled estimate.

Potential biases in the review process

By performing a thorough search that encompassed numerous databases of publications and sources of unpublished material, we attempted to prevent publication bias. To lower the possibility of overlooking a study that should have been included, three persons went through all of the search results. The review authors then checked the studies that could have been included to confirm that the inclusion criteria had been consistently fulfilled.

Agreements and disagreements with other studies or reviews

There was a difference in total and average costs of telerehabilitation and usual care in our study which was also reported in other review studies. Few included trials reported that there was no significant difference in cost,[19] but in disagreement, many studies reported that telerehabilitation was cost-saving and had an overall reduction in hospital admissions and complications. A study conducted by Dar in London reported no difference in quality of life and mortality risk for those allocated to telemedicine and the usual treatment group.[28] The above study was designed to focus on hospital readmissions for a particular health outcome and was not designed to detect differences in mortality between treatment groups. However, trials that focussed on mental health problems like Post-traumatic stress disorder and depression showed that Telerehabilitation services were effective and reported a greater QALY.[29,30] The exclusion of small studies is an approach we will use in the next update, as the inclusion of a large number of small studies limits the extent to which the review can remain in date. This review excluded those lacking specific economic data or detailed economic evaluations and those focusing on telemedicine outside the scope of rehabilitation services. Our results of lower cost for telerehabilitation than in controls agree with results from two other systematic reviews.[19,31] Another review reported no difference between Telerehabilitation and usual care,[32] but included qualitative, observational and cross-over studies. Depending on the study design and primary outcome studied, there is a difference in opinion on the use of Telerehabilitation services. Overall, many studies have found a significant improvement or no difference in the use of telerehabilitation and usual treatment groups. However, no studies have shown strong evidence suggesting that telerehabilitation is less effective than usual or conventional treatment. Therefore, it is safe to conclude that telerehabilitation doesn’t worsen the existing outcome and has better feasibility when compared to standard treatment options.

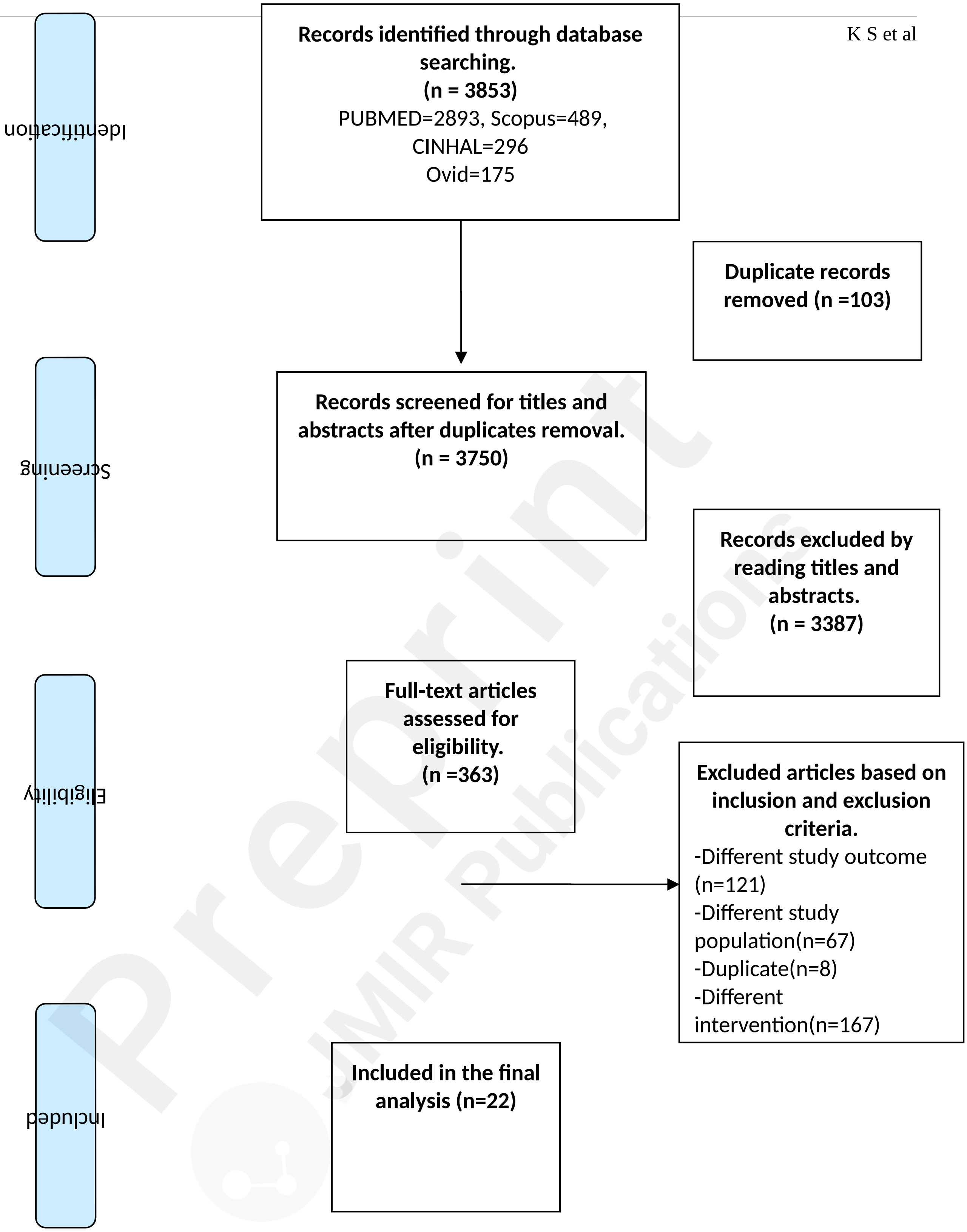

Figure 1: PRISMA flow diagram showing the study selection process.

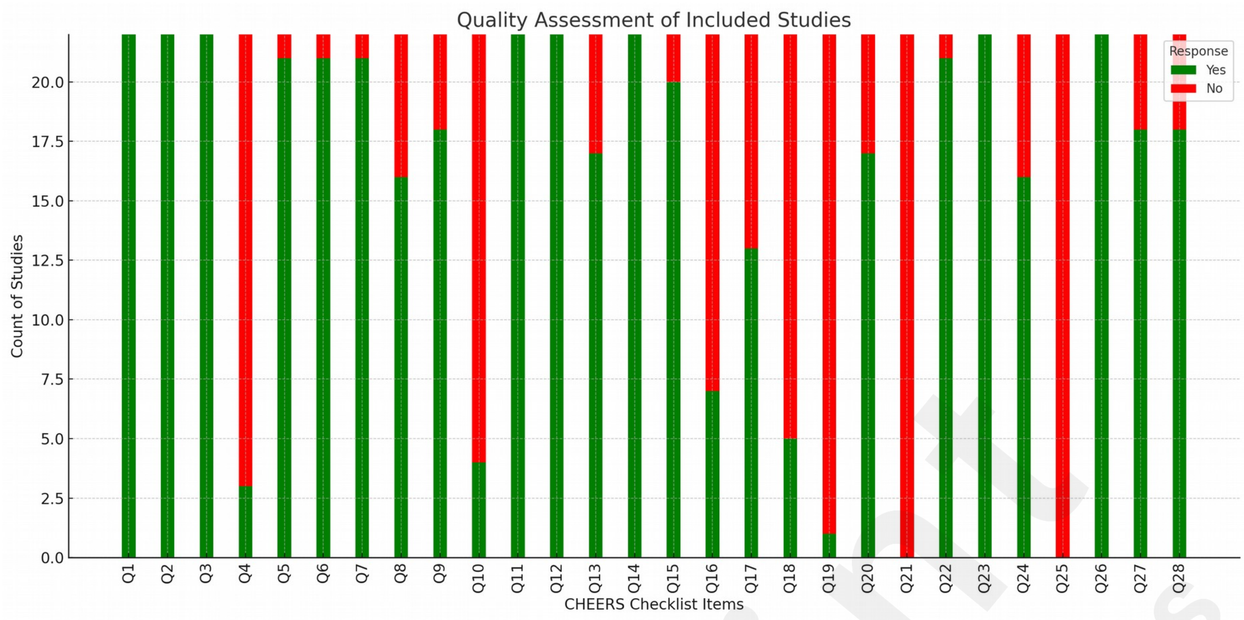

Figure 2 Quality assessment using CHEERS checklist

Table 1 Basic characteristics of included studies

Author, Year, Place	Study design	sample size	Types of Telehealth Intervention	Comparator outcome	Outcomes (Total Cost - Intervention)	Outcomes (Total Cost - Control)	Average cost (Intervention)	Average cost (control)
Jeffrey M. Pyne, 2010, US	RCT	395	A telemedicine-based collaborative care depression intervention.	Usual care.	-	-	$10602.52	-
Osiane JJ Boyne et al, 2013, Netherland	RCT	382	Telemonitoring Programm	Usual care (UC) program	€ 16,687	€ 16,561		
Valentina Isetta et.al, 2015, Spain	RCT	139	telemedicine impact on treatment compliance	traditional face-to-face follow-up.	€ 11,619.60	€ 12,628	€313.45	€335.78
Ines Frederix et al, 2015, Belgium	RCT	140	Telerehabilitation programme	conventional cardiac rehabilitation	€2156 ± €126 per patient	€2720 ± €276 per patient		
Kristian Kidholm et.al, 2016, Denmark	RCT	151	Cardiac telerehabilitation (CTR) program	Traditional rehabilitation program at the hospital	€ 5,709	€ 4,045	€ 924.35	€ 654.95
Christopher M. Celano, 2016, US	RCT	183	collaborative care	Usual care	$48,287	$20,920	$261.78	$43.15
Benjamin I. Rosner	cohort stud	558	Automated digital patient	The study involved a proximate	$9317.91	$8534.91	$797.23	$160.08

et.al, 2017, California	y		engagement (DPE) platform	historical control, comparing patients undergoing total joint arthroplasty (TJA) from the same physicians at the same practices before platform implementation.				
Jacob T Painter et.al, 2017, US	RCT	265	telemedicine-based collaborative care model	standard PTSD care provided	$9482.88	$9544.38		
Mark Nelson et.al, 2019, Australia	RCT	70	Telerehabilitation program	Traditional in-person care	$487.22	$516.12		
Francis Fatoye et.al, 2020, Nigeria	RCT	47	Telerehabilitation-based McKenzie therapy (TBMT).	Clinic-based McKenzie therapy (CBMT).	$61.7	$106.22	$71.52	$122.88
Xinchan Jiang et.al, 2020, China	RCT	10913	Telemonitoring-guided management	Physician's office visits	$243,423	$238146		
Colleen F. Longacre et.al, 2020, United States	RCT	516	Tele-rehabilitation interventions	Usual care	$30481	$14130	$179.61	$179.61
Maciej	RC	795	Hybrid	Standard	1776	7644	214.07	276.3

Niewada et.al, 2021, Poland	T		telerehabilitation	care	PLN	PLN	PLN	6 PLN
Rutger W. M. Brouwers et.al, 2021, Netherland	RCT	300	Cardiac telerehabilitation (CTR)	Centre-based cardiac rehabilitation (CR)	$39168	$26166	$6678.86	$8774.46
Kristina Aspvall, 2021, Sweden	RCT	152	Stepped-care group utilizing telehealth methods	in-person cognitive behavioural therapy group.	$6081	$7527	$426.77	$688.73
Yong Yi Lee, 2022, Australia	RCT	1868	a person-centred e-health platform	usual care.	$5554769.99	$856544.52	$8180.81	$1263.34
Astrid Langergaard et al, 2022, Denmark	RCT	76	online modules	face-to-face consultations	£1118.4	£1946.81		
Sameera Senanayake et.al, 2023, Nigeria	RCT	47	Hybrid cardiac telerehabilitation program	Traditional centre-based cardiac rehabilitation	20600000 $	20000000$	$432.31	$163.1
Tianyi Liu et.al, 2023, China	RCT	100	Digital therapeutics	Conventional home-based cardiac rehabilitation	42,300.26 CNY	38,442.11 CNY	11986.47 CNY	
Anthony Harris et.al, 2023, Australia	RCT	415	Telehealth-delivered exercise programs	Education control group	1,678 $	1,356 $	$1602.63	$1573.6
Tianyi Liu,	RCT	2315	Digital therapeutics	Conventional home-	42,300.26 CNY	38,442.11	21275.3 CNY	20961.37

2023, Mainland China			(DTx)	based cardiac rehabilitation		CNY		CNY
Klemen Naversnik, 2023, Slovenia	RCT	46	Improve health.eu e-health service	usual care for depression.	€ 1,368.51	€ 1,216.08	€1368.51	€1216.08

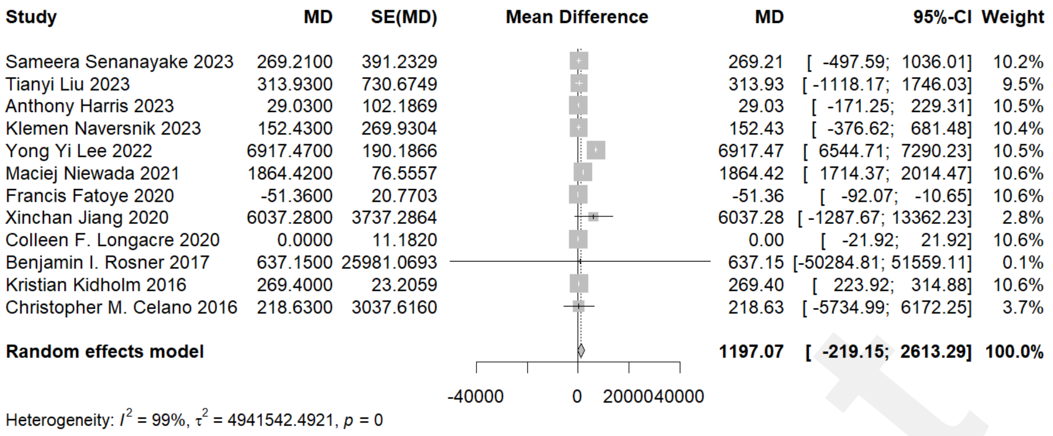

Figure 3 Forest plot showing the total cost of intervention.

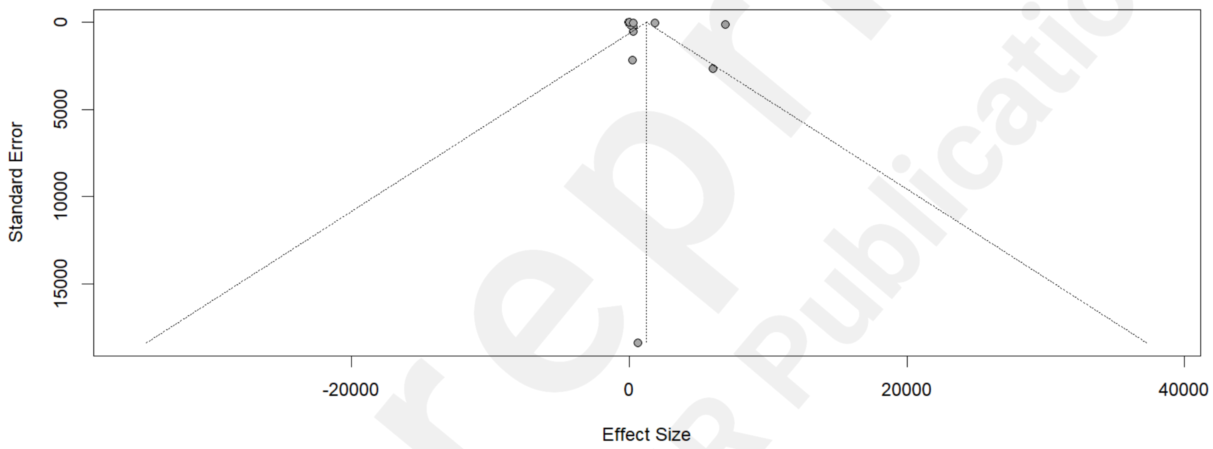

Figure 4 Funnel plot

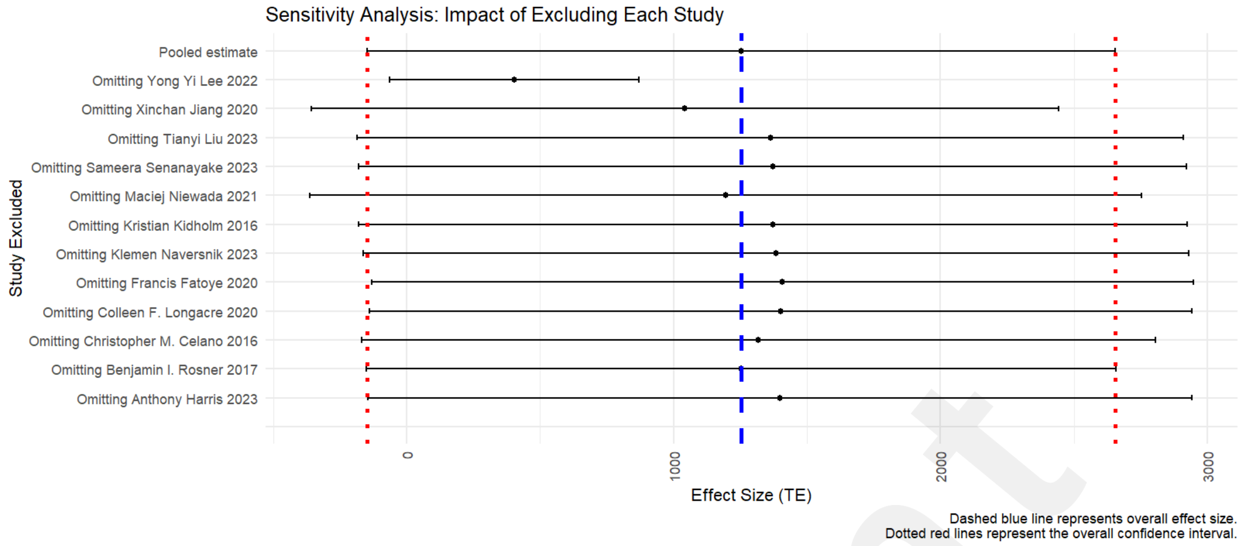

Figure 5 Sensitivity analysis

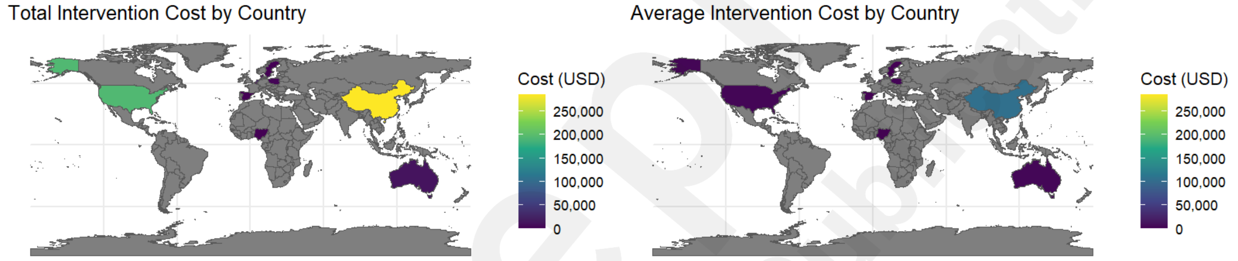

Figure 6 Subgroup analysis

Appendix

Author,year,place	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28
JeffreyM. Pyne et al,2010, USA	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✗	✓	✓	✓	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
osiane JJ Boyne et al,2013, Netherla	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✗	✓	✓	✓	✗	✓	✓	✗
Ines Frederix et al, 2015, Belgium	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✗	✗	✓	✗	✗	✗	✗	✓	✓	✗	✗	✓	✓	✓
Valentina Isetta et al, 2015, Spain	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Kristian Kidholm et al, 2016, Denmar	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Christopher M. Celano et al, 2016, U	✓	✓	✓	✗	✓	✓	✓	✗	✗	✗	✓	✓	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	✓	✗	✗
Benjamin I. Rosner et al, 2017, USA	✓	✓	✓	✗	✓	✓	✓	✗	✓	✗	✓	✓	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	✓	✓	✓
Jacob T Painter et al, 2017, USA	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✗	✗	✗	✓	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Mark Nelson et al,2019, Australia	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Francis Fatoye et al, 2020, Nigeria	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Xinchan Jiang et al, 2020, China	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✗	✓
Colleen F. Longacre et al, 2020,USA	✓	✓	✓	✗	✓	✓	✓	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Maciej Niewada et al,2021, Poland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✗	✓	✓	✗	✗	✓	✓	✓
Rutger W. M. Brouwers et al, 2021, N	✓	✓	✓	✗	✗	✗	✗	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Kristina Aspvall et al, 2021, Sweden	✓	✓	✓	✗	✓	✓	✓	✗	✗	✗	✓	✓	✗	✓	✓	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✓	✗	✗
Yong Yi Lee et al,2022, Australia	✓	✓	✓	✗	✓	✓	✓	✗	✗	✗	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	✓	✗	✗
Astrid Langergaard et al,2022,Denm	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Sameera Senanayake et al, 2023, Au	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Tianyi Liu et al, 2023, China	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Tianyi Liu et al, 2023, China	✓	✓	✓	✗	✓	✓	✓	✗	✗	✗	✓	✓	✗	✓	✓	✗	✗	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Anthony Harris et al, 2023, Australia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Klemen Naversnik et al, 2023, Slover	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓

Supplementary table 1 Quality assessment of individual studies

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Supplementary Files

Untitled.

Author, year, nation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28
Jeffrey M. Pyne et al.2018, USA	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✗	✓	✓	✓	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Joanne J.Bourne et al.2021, Netherlands	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✗	✓	✓	✓	✗	✓	✓	✗
Ines Frederix et al. 2015, Belgium	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✗	✗	✓	✗	✗	✗	✗	✓	✓	✗	✗	✓	✓	✓
Valentina Isetta et al. 2015, Spain	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Kristian Kidholm et al. 2018, Denmark	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Christopher M. Delano et al. 2018, USA	✓	✓	✓	✗	✓	✓	✓	✗	✗	✗	✓	✓	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	✓	✗	✗
Benjamin L. Rosner et al. 2017, USA	✓	✓	✓	✗	✓	✓	✓	✗	✓	✗	✓	✓	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	✓	✓	✓
Jacob T Painter et al.2017, USA	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✗	✗	✗	✓	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Mark Nelson et al.2018, Australia	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Francis Fatoye et al. 2020, Nigeria	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Xinchun Jiang et al. 2020, China	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✗	✓
Colleen F. Longacre et al. 2020, USA	✓	✓	✓	✗	✓	✓	✓	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Maciej Niewada et al.2021, Poland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✗	✓	✓	✗	✗	✓	✓	✓
Rutger W. M. Brouwers et al. 2021, Nether	✓	✓	✓	✗	✗	✗	✗	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Kristina Aspvall et al. 2021, Sweden	✓	✓	✓	✗	✓	✓	✓	✗	✗	✗	✓	✓	✗	✓	✓	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✓	✗	✗
Yong Y Lee et al.2022, Australia	✓	✓	✓	✗	✓	✓	✓	✗	✗	✗	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	✓	✗	✗
Astrid Langergaard et al.2022 Denmark	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Samanta Senanayake et al. 2023, Australia	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Tianyi Liu et al. 2023, China	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Tianyi Liu et al. 2023, China	✓	✓	✓	✗	✓	✓	✓	✗	✗	✗	✓	✓	✗	✓	✓	✗	✗	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Anthony Harris et al.2023, Australia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓
Damien Nowatnik et al. 2023, Slovenia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓

Figures