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A systematic review of remote rehabilitation (telerehabilitation) services to support people with vision impairment.

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Title: A systematic review of remote rehabilitation (telerehabilitation) services to support people with vision impairment.

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ABSTRACT

Objective: To describe the nature of telerehabilitation services available to people with vision impairment and summarise available evidence relating to effectiveness.

Design: Systematic review.

Data sources: CINAHL Plus, MEDLINE, PsycARTICLES, PsychINFO, Embase, PubMed, HMIC and Ovid Emcare were searched, without date restrictions up to 24 May 2021. A detailed search of online grey literature was also conducted.

Eligibility criteria: Eligible studies evaluated effectiveness of telerehabilitation services for visually impaired people. Studies were excluded if they did not relate to remote service delivery, were not available in English, or focused on distance learning of visually impaired students.

Data extraction and synthesis: Two independent reviewers screened articles and extracted data. A risk of bias analysis was performed.

Outcome measures: Measures of effectiveness included performance-based assessment, patient-reported outcomes, and cost-effectiveness.

Results: Of 4,472 articles, 10 eligible studies were included. Four studies (33.3%) addressed patient satisfaction and recommendations, two studies (16.6%) related to vision training, four studies (33.3%) measured patient-reported outcomes and well-being, one study (8.3%) addressed managing clinical symptoms and one study (8.3%) analysed cost-effectiveness. Two studies featured across multiple domains.

Conclusion: Publication trends suggest telerehabilitation is increasingly featuring in the low vision rehabilitation care pathway. Patients are generally accepting of this model and may benefit from improved functional and quality-of-life outcomes. This systematic review highlights that further trials are needed to evaluate telerehabilitation using a robust set of outcome measures.

PROSPERO registration number: CRD42021254825

Strengths and limitations of this study

- This review provides novel findings informing design of future trials and evaluations of telerehabilitation.
- Inclusion of grey literature reduces publication bias and increases the comprehensiveness of the review.
- Only articles written in English were included and results were seldom disaggregated by disease type or severity.

INTRODUCTION

Visual impairment is a broad term used to describe a reduction in visual sensitivity that cannot be corrected by standard eyeglasses or medical treatment. It is estimated that over 2 million people in the United Kingdom (UK) are living with a form of visual impairment [1]. Visually impaired individuals may be classified as 'sight impaired' (i.e., partially sighted) or 'severely sight impaired' (i.e., legally blind) [2]. The impact of visual impairment can be complex and highly heterogenous, affecting aspects of daily functioning, mobility, and quality of life [3-8]. Among the widely prevalent ophthalmic conditions such as age-related macular degeneration, glaucoma, and diabetic retinopathy, loss of vision is typically progressive and irreversible; hence, support heavily relies on rehabilitation to promote adaption, enabling patients to better manage the challenges associated with vision loss and to live an independent and fulfilling life [9, 10].

The mainstay of rehabilitation is to restore or maintain physical and/or psychological functioning to the maximum degree possible in individuals living with disease or injury. In vision rehabilitation, eye care providers are encouraged to provide rehabilitative support or refer patients to relevant services, even in cases of mild or moderate sight loss [11]. Rehabilitation encompasses many disciplines, and interventions may include provision of visual aids, devices and software, behavioural training, home environment assessments and adaptions, social and psychological support, leisure and vocational activities, or a combination of these strategies [12, 13]. However, rehabilitation is characteristically structured around overcoming the practical and functional challenges of sight loss, whilst psychological outcomes are seldom addressed directly [14]. The type of services which are offered often depends on the nature of the visual impairment. For example, the rehabilitative needs of individuals with central visual field loss may differ from those with impaired peripheral vision [15]. The traditional mode of delivery for vision rehabilitation has been in face-to-face settings within outpatient clinics or home visits by low vision specialists or allied health professionals; though digital developments have increased opportunity for remote service delivery (i.e., telerehabilitation).

Telerehabilitation, also known as virtual training or e-learning, refers to delivering rehabilitative services using a remote or virtual approach, facilitated by telecommunication technologies. Services may comprise a range of elements designed to assess, prevent, treat, educate, or counsel individuals living with chronic health conditions [16]. Telerehabilitation services may be synchronous, whereby services are delivered in real-time using two-way video or audio communication, or asynchronous, such as remote evaluation of recorded videos or other measurements such as surveys or psychophysical testing [17]. Compared to traditional face-to-face rehabilitation, telerehabilitation offers potential benefits, such as reduced costs, increased geographical accessibility, and creating opportunities to extend limited resources [18]. Moreover, telerehabilitation has been identified as an effective means of delivering support to individuals with chronic conditions including multiple sclerosis, osteoarthritis, and stroke [19-21].

Whilst there is convincing evidence to suggest telerehabilitation can be effective at improving physical and psychological functioning in people living with chronic health conditions, less is known about the effectiveness of telerehabilitation services for people with a vision impairment. For example, a previous review sought to compare outcomes between face-to-face and virtual vision rehabilitation services, yet no completed studies in this area were found [22]. Additionally, new services emerging during the COVID-19 pandemic have yet to be reviewed. This is significant given the rapid and extensive scale-up of telehealth services since the beginning of the pandemic [23, 24]. This systematic review, therefore, aims to draw together evidence on telerehabilitation services, and describe their impact on health and well-being outcomes in people with vision impairment.

Objectives

1. Describe the nature of telerehabilitation services available to people with vision impairment.
2. Collect and summarise evidence on the impact of telerehabilitation in terms of health-related outcomes, well-being and cost-effectiveness.

METHODS

This review follows best practice for conducting systematic reviews as outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist to ensure all aspects of the process are undertaken using rigorous and transparent methods [25, 26]. A search of the electronic databases CINAHL Plus and MEDLINE (via EBSCOhost) and PsycARTICLES, PsychINFO, Embase, PubMed, HMIC and Ovid Emcare (via Ovid) was undertaken. As recommended by The Cochrane Handbook for Systematic Reviews of Interventions, medical subject headings (MeSH) were used to identify the most relevant articles [27]. MeSH terms are official words or phrases selected to represent medical concepts and are assigned to articles in order to describe what the research item is about [28]. This process provided a list of keywords relating to vision impairment and telerehabilitation. For detailed search terms, see Table 1. Reference lists of included studies and any identified systematic reviews were also reviewed for relevant articles, and citation tracking was performed using Google Scholar.

Vision impairment term		**Telerehabilitation term**
vision OR low vision OR vision loss OR reduced vision OR subnormal vision OR diminished vision OR vis* impair* OR sight loss OR blind* OR partially sighted	AND	telerehab* OR tele-rehab* OR remote rehab* OR virtual rehab* OR e-learning OR online learning OR online training OR telephone training OR telephone rehab* OR telephone learning OR virtual learning OR web training OR virtual training

Table 1. Search terms

In addition, we reviewed online conference proceedings for relevant abstracts. A search of grey literature included searching for relevant articles or reports on the websites of organisations such as the UK National Institute for Health and Clinical Excellence (NICE; www.nice.org.uk) and National Health Service (NHS) Evidence (www.evidence.nhs.uk). We also conducted an extensive search of the UK Charity Commission website to identify organisations with links to vision impairment and rehabilitation. Relevant charity websites were then searched and in cases where telerehabilitation was documented, any available documentation was downloaded and reviewed, and charities were contacted to enquire about the current status of telerehabilitation.

Articles written in English, with no restrictions on publication period, and only where the full text was available were included. Studies were further required to address the exposure of interest (i.e., visual impairment and telerehabilitation). Articles were excluded if they did not relate to remote service delivery (i.e., face-to-face services). Articles focusing only on an educational context were also excluded. For example, visually impaired students using home technology for distance learning.

Two authors (LJ and ML) independently screened studies using Covidence systematic review software (Veritas Health Innovation Ltd, Melbourne, Australia; available at www.covidence.org) to assess eligibility. Any disagreement in coding decisions were resolved through discussion. Relevant information (e.g., publication details, characteristics of participants, study design, outcomes measured, study results, and conclusions) from eligible articles was entered into a data extraction table.

Studies were assessed for quality using Kmet *et al.* '*Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields*' [29]. This quality appraisal tool was chosen because of both quantitative and qualitative studies emerging from the literature search. This review is registered online with the International prospective register of systematic reviews (PROSPERO; www.crd.york.ac.uk/prospero/; Reference CRD42021254825).

Patient and public involvement

No patients were involved in the design of the review. We will disseminate plain language summaries to relevant patient groups including members of Blind Veterans UK.

Research ethics approval

Ethical approval for this systematic review was not required.

RESULTS

Searches were run on 24 May 2021 and yielded 4,472 results. Of these, 658 were automatically removed as duplicates. This left 3,814 studies to screen using title and abstract, of which 3,719 were excluded and 95 were assessed for full-text eligibility. Studies were mostly excluded at the title and abstract screening stage because they did not relate to telerehabilitation or did not involve visually impaired individuals. These two reasons were also the primary cause for exclusion at the full-text review accounting for 17 and 38 exclusions, respectively. A further two studies were added through reference list searching. Ultimately, 10 full-text studies were selected for inclusion. The study selection process is shown in the PRISMA diagram in Figure 1.

<Insert Figure 1 here>

Figure 1. PRISMA diagram showing study selection process. Key: VI = vision impairment

Quality appraisal was conducted on all 10 studies. The lowest score was 0.64, the highest was 1.00 (i.e., all responses to relevant questions in the Kmet *et al*. appraisal criteria were 'Yes'), and the median score was 0.93. The most frequent issues with the studies were the presence of only a partial description of subject characteristics (2 of 10) and study conclusions not being fully supported by the data (3 of 10); however, this was the case for just a small proportion of the studies.

The following overview of study findings is organised according to the main outcome domains for each of the 10 articles identified in the systematic literature search. Two articles feature in more than one section as the outcomes were translatable across multiple domains. Four studies (33.3%) addressed patient satisfaction and recommendations, two studies (16.6%) related to vision training, four studies (33.3%) measured patient-reported outcomes and well-being, one study (8.3%) addressed managing clinical symptoms and a further one study (8.3%) was an analysis of cost-effectiveness. For full details of the included studies, refer to the data extraction table (Supplementary material).

Patient satisfaction and recommendations

Four articles explored patients' satisfaction with telerehabilitation and recommendations for key features to improve uptake of services. Three of these articles reported the findings of feasibility studies and one was a qualitative analysis of patient experiences. All of these studies included participants with a visual impairment caused by a range of pathologies including age-related macular degeneration, optic nerve disease, retinitis pigmentosa, and stroke-related visual field deficit.

Dunne *et al.*'s [30] study of stroke survivors reports the outcomes of qualitative interviews and focus groups with patients and carers. The study was informed by the findings of a survey of Stroke Association group members in the UK and the aims were to understand experiences of a compensatory eye-movement tool and training packages. The Durham Reading and Exploration Training (DREX) is a computer-based telerehabilitation training system teaching adaptive eye movement strategies to enable stroke survivors to cope more effectively with visual field deficits. DREX is a mobile application which incorporates tasks that combine both reading and exploration (e.g., scanning an array to locate a target). The wider study required patients with stroke-related visual field defects to complete the DREX trials on a tablet in their own homes and outcomes were compared to a control intervention, which consisted of attention-based tasks with no eye movement or exploration exercises. Significantly greater gains were observed in performance, visual functioning and everyday behaviours following DREX than the control intervention [31]. Qualitative responses highlighted a range of issues in the application of telerehabilitation for visually impaired stroke survivors. For example, a lack of confidence with technology, perceived fear of making mistakes while online, distrust of the quality of the intervention, and concerns with reduced face-to-face contact. However, these issues could be addressed in initial in-person visits to alleviate concerns and facilitate engagement and motivation in the rehabilitation process. One challenge is that compensatory training is inherently repetitive in nature; thus, measures should be taken to ensure telerehabilitation tools remain accessible to avoid disengagement. The authors propose one approach which may obviate disengagement is to employ feedback and goal setting to improve motivation and provide tangible progress updates.

Patient satisfaction was assessed by Bittner *et al*. [32] in a pilot study to develop, administer and evaluate a synchronous virtual low vision portal providing telerehabilitation services. Ten patients diagnosed with either age-related macular degeneration (n = 9) or diabetic retinopathy (n = 1) were enrolled. Participants were required to have access to a home telephone to use the Internet-based video conference portal. Tablet devices were provided as well as MiFi (wireless router which acts as a mobile Wi-Fi hotspot) to enable connection to the Internet. Each participant received one telerehabilitation session which lasted approximately one hour. The session included administration of the MNREAD chart which consists of a series of 60-character sentences displayed over three lines and is used to assess reading fluency and proficiency using optical magnifiers, using video and audio recordings of the participant. Assessments of working distance and lighting were made by the provider viewing the video of the participant reading with their magnifier, whereas assessments of reading speed and accuracy relied on the audio component as participants read aloud during the MNREAD and near acuity tests. The outcomes were participants' and providers' audio and video quality ratings. Video quality was rated as excellent to good, whereas audio ratings were more variable. All participants were satisfied and comfortable receiving telerehabilitation and evaluation via videoconferencing. Eight of 10 reported that their magnifier use improved after telerehabilitation. All except one reported that they were very interested in receiving telerehabilitation services again if their visual needs changed.

Lorenzini and Wittich report outcomes related to patient satisfaction in a feasibility study using a head-mounted video platform to deliver synchronous telerehabilitation sessions at home [33]. Participants received real-time distance training sessions delivered by a low vision therapist. The intervention focused on the technical aspects of using eSight eyewear, an assistive technology designed to maximise visual input and compensate for vision loss. The intervention group underwent a personalised training programme including eSkills functional learning activities such as reading, writing, and distance vision training. A control group were allocated to conventional eSight self-training using the eSkills user guide. Fifty-seven visually impaired participants were enrolled (experimental group, n = 28), the most common causes of sight loss were optic nerve disease, age-related macular degeneration, retinopathy of prematurity, and retinitis pigmentosa. Retention rates during the study were 93% (n = 53) at 2 weeks, 68% (n = 39) at 3 months, and 65% (n = 37) at 6 months. A higher proportion of patients who withdrew from the study were enrolled into the control group. Participants reported being comfortable with receiving telerehabilitation training at home, with 16 of 23 (66%) agreeing the programme was effective and efficient, and the majority (20 of 23) approving that they would be interested in using telerehabilitation again in the future.

A parallel investigation by Lorenzini and Wittich used standardised measures to assess quality of life and patient satisfaction following the eSight telerehabilitation programme [34]. Quality of life outcomes are reported in a later section. Satisfaction was measured using the 12-item Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST) tool. Scores on the measure increased for participants in both the experimental and control group between baseline and 3-months of device usage, suggesting satisfaction improved independently of the type of training. There were no differences in assistive technology-related satisfaction based on age or sex. Improvement in QUEST scores were not maintained at 6-months. The authors suggest this may be due to the device no longer meeting certain needs after extended usage, or a lessening impact of social desirability, leading to more realistic and honest responses from participants over time.

Vision training

Two studies focused on training related to optimisation of vision delivered through a telerehabilitation service. Both studies included patients with measurable visual field loss including areas of diminished sensitivity in glaucoma and hemianopia in stroke patients.

Sabel and Gudlin compared outcomes of behavioural training using a 1-hour computer-based vision restoration programme for people with glaucoma and a placebo group [35]. Participants were required to have a stable glaucomatous visual field defect inside 30° eccentricity in at least one eye, with well controlled intraocular pressure. After baseline assessments, training was performed 6-days per week for 3-months at home on a commercially available computer with adaptive parameter adjustments. The experimental group performed vision training similar to perimetry whereby visual stimuli of varying luminance are presented in areas of residual vision.

The placebo group performed stimulus discrimination training. Vision restoration exercises led to improved vision-related performance (detection accuracy and faster reaction time) without affecting eye movements. The authors conclude that visual system plasticity can be retained into older age despite widespread visual deterioration and activation of residual vision may partly reverse vision loss.

A study on patients with hemianopia used a bespoke asynchronous audio-visual telerehabilitation system [36]. The system featured a semi-circular apparatus in which visual and acoustic stimuli are presented and a central camera to control head and eye movements. Patients used the system at home on a customised tablet which was controlled by a hospital-based therapist. Following an initial assessment in the clinic, participants underwent training at home at least 5 days a week for up to 12 months. The aim of the training was to stimulate multisensory integration mechanisms to reinforce visual and spatial compensatory functions, for example, adoption of oculomotor strategies. Among the sample of three adults with hemianopia, all were capable of actively using the device independently whilst under remote supervision and showed improvements in visual detection abilities over the study period. The authors conclude that the device may contribute to better visual outcomes and could be used to reduce the need for one-to-one hospital visits.

Quality-of-life and well-being

Four articles assessed outcomes relating to quality-of-life and well-being following telerehabilitation. The studies use patient-reported outcome measures and behavioural measurements to examine the effectiveness of remote interventions in people with a vision impairment. Two articles are case reports, and two articles describe the quality-of-life outcomes from the eSight eyewear and vision restoration training programmes described in an earlier section.

Lorenzini and Wittich [34] measure changes in quality-of-life following telerehabilitation with the eSight eyewear programme using the Psychosocial Impact of Assistive Devices Scale (PIADS), a 26-item questionnaire composed of three subscales (competence, adaptability, and self-esteem), and the Veterans Affairs Low Vision Visual Functioning Questionnaire (VA LV VFQ-48), a 48-item instrument used to measure outcomes of patients receiving low vision rehabilitation. Visually impaired participants completed the measures at baseline, 2-weeks, 3-months, and 6-months. Results patterns were similar across the three subscales of the PIADS showing statistically significantly improved scores after 3 months in both the intervention and control groups, indicating that assistive technology-related quality-of-life (i.e., perceived impact of assistive devices on quality-of-life) improved independently of the type of training received. Self-reported functional vision outcomes, as determined by the VA LV VFQ-48, yielded statistically significant improvements in overall scores, as well as in all subscales (reading, visual information, mobility, visual motor) after 2 weeks of using the device; improvements also continued after 3 months.

Sabel and Gudlin's [35] vision restoration programme used the National Eye Institute Visual Function Questionnaire (NEI-VFQ-25) and the Short-Form-36 (SF-36) to measure changes in quality of life between baseline and post-intervention follow-up. Vision training was not associated with robust changes on these measures. Only the mental health subscale of the SF-36 was found to have improved, which may be caused by non-specific training effects such as attention, alertness, or expectation. However, participants had generally scored highly on both measures at baseline, indicating few everyday vision deficits.

A case report by Dogru-Huzmeli *et al*. [37] explored whether diplopia complaints could be ameliorated using the Cawthorne-Cooksey exercises applied via telerehabilitation in a multiple sclerosis patient with a visual field scotoma. Cawthorne-Cooksey exercises use a set of eye and head movements which are based on the concept of habituation and designed to build up a tolerance mechanism to support equilibrium and balance. Exercises were delivered through WhatsApp video calls over 30 sessions. Comparison of pre- and post- eye examinations suggested gaze restriction had improved and that the patient had fewer double vision complaints. Pre- and post-intervention quality-of-life was assessed using the SF-36 measure of general health. The authors report improvement in all domains of the SF-36, except for physical functioning, where there was no change.

A study from Lancioni and colleagues assessed whether two congenitally blind women could be supported to make independent phone calls using a computer-aided system [38]. Both women attended a rehabilitation centre where the study took place. The system comprised of a netbook computer which was enabled with a global system for mobile communication with a headset and microphone apparatus. The study adopted an ABAB design in which A represented baseline phases and B represented intervention phases with the telephone system. Communication-related outcomes included the total number of calls made, number of calls met with a response, and length of calls. Both participants learnt to use the system and made phone calls independently to a variety of contacts such as family members, friends, and care staff personnel, indicating that the intervention may be useful for enabling people with a vision impairment to manage phone calls on their own.

Managing symptoms

One study used a telerehabilitation approach to support patients attending a residential school for visually impaired people during the COVID-19 pandemic. Senjam and colleagues [39] used voice-over internet protocols (e.g., WhatsApp calling, Zoom) to enable a rehabilitation team to deliver education and counselling interventions and monitor ocular complaints among visually impaired adults and children. Over a 2-month study period, 492 patients contacted the team. Health-related complaints were made by 335 patients, the most common ocular complaints being itching (36.1%), watering (16.1%), and painful eyes (3.6%). Counselling sessions addressed uncertainty surrounding clinical monitoring of eye health. The study suggests that preventative strategies to help manage ocular symptoms could be delivered through telerehabilitation, although the outcome of interventions was not known.

Cost-effectiveness

A retrospective cost analysis from Ihrig [40] examined the economic practicality of a clinical model of telerehabilitation for visually impaired military veterans. Telerehabilitation was delivered by an optometrist and rehabilitation therapist to veterans with conditions including age-related macular degeneration, glaucoma, diabetic retinopathy, cataracts, and retinitis pigmentosa. Sessions took place remotely at either the participants' home or local community outpatient centre. Total and median travel cost and time savings were estimated per veteran per fiscal year. Introduction of the telerehabilitation service in 2012 increased access to rural veterans in Western New York. Over a 5-year period, 419 veterans who were unable to access traditional low vision rehabilitation due to travel issues accessed the remote service. The proportion of patients accessing the telerehabilitation service represented 24% of the overall rehabilitation caseload. Median saving of travel miles was 122 miles per veteran (51,136 miles/419 veterans). Median saving of travel time was 2.09 hours per veteran (878 hours/419 veterans). Overall, median travel cost saving per rural individual was $65.29 per veteran ($27,357.76/419 veterans). The authors conclude that telerehabilitation can be a practical, time-saving, and cost-saving alternative to traditional face-to-face consultations.

Grey literature

Searches of charity websites led to the identification of 11 organisations in the UK where vision rehabilitation services had been shifted to remote delivery. The charities were contacted about the nature of services and whether any evaluations had been undertaken. This process resulted in the review of seven documents, predominantly internal reports about the restructure of rehabilitation services during the COVID-19 pandemic. While these documents were mostly descriptive, there was useful information demonstrating telerehabilitation practice patterns in the third sector. For example, Blind Veterans UK, a charity providing support and services to visually impaired UK veterans, reported information about the needs of their beneficiaries, experimental methods in delivering remote rehabilitation, and working with allied agencies throughout the COVID-19 pandemic to signpost members to support. Similarly, charities such as Royal National Institute of Blind People and National Federation of the Blind describe telerehabilitation frameworks which have been implemented during the pandemic.

Trends in publishing

There has been an increase over time in published studies evaluating the impact of telerehabilitation on people with a vision impairment. Yet, these studies represent only a small proportion of the total research on people with vision impairment. For example, a PubMed search for articles with ‘vision impairment’ or ‘blindness’ in the title or abstract yields 17,783 results since 2010 alone; while in that same period just 10 articles (0.06%) were published that were relevant to telerehabilitation and were included in this review.

Discussion

Vision rehabilitation is a key stage in the eye care journey. Rehabilitative services can help to mitigate the impact of vision loss by equipping patients with new skills and training while providing social connectedness and psychological support [41-45]. This review shows that the landscape of rehabilitation is evolving to include synchronous and asynchronous approaches to remote rehabilitation for people with sight loss conditions. Studies using patient-reported outcome measures suggest telerehabilitation can lead to improved outcomes relating to daily functioning and quality-of-life. In addition, there is generally a high level of acceptability from patients for this shift in service delivery. However, there remain certain distinct challenges associated with telerehabilitation which may curtail the extent to which this approach is adopted and retained more widely.

Several of the studies in this review included recommendations for telerehabilitation which provide helpful insights. For example, a period of direct training with home-based technology was regarded positively, suggesting such training can provide patients with a helpful rehabilitation framework. Despite an increasing number of visually impaired adults engaging with technology [46], it is inevitable that some individuals will have underlying concerns about their technical readiness to operate devices at home. An assessment of individual self-efficacy regarding health management and aptitude for telerehabilitation may, therefore, help to prioritise individuals for whom this approach is most likely to be tolerated and successful.

A key challenge associated with telerehabilitation is maintaining patient motivation and engagement. Rehabilitation is, by nature, highly repetitive and often requires continuous engagement over long periods of time before measurable effects can be observed. Although studies in this review yielded good patient satisfaction ratings [34] and high retention rates [33], it is difficult to predict the sustainability of telerehabilitation outside the context of a research study. For example, devices risk becoming a nuisance if required long term, and whilst acceptable within research, patients may resist such commitments becoming the standard of care [47]. Studies in this review described intensive programmes of telerehabilitation, in some instances requiring several hours of engagement per week. Further research using real-world data on patterns of engagement with telerehabilitation will be a valuable addition to the literature and could help to identify factors associated with adherence and withdrawal, and behavioural strategies to encourage adoption.

One aspect of telerehabilitation which increases its appeal is the potential for substantial direct and indirect cost savings. The 2019 study by Ihrig [(40)] highlighted that telerehabilitation was associated with considerable time and cost savings for patients by reducing travel requirements and fuel consumption. However, in cases where individual specialist equipment was required, such as the adapted telephone system in the study from Lancioni and colleagues [(38)], costs per unit were expected to be in the region of $2,000 USD. The economic value of telerehabilitation from a provider perspective requires more research. For example, additional costs may be incurred for services such as training, measurement readings, data management, and ongoing maintenance of many devices. Indeed, remote service delivery has been associated with slightly higher costs to service providers, such as speech therapy in people with Parkinson's disease [(48)]. Nevertheless, it could be expected that remote rehabilitation costs would be largely absorbed by the reduced need for time and resources required for non-remote services. It is noteworthy that telerehabilitation may have a wider reach than standard rehabilitation services, and the increased availability and convenience of a remote service may be more appealing to a broader profile of patients (e.g., working age individuals with minimal time for in-person sessions). As shown by Ihrig [(40)], remote service delivery led to an average workload increase of 24% due to a higher number of patents accessing the service. If this finding applied to a broader audience, there will likely be a larger rehabilitation patient caseload, with possible capacity implications for clinical practice.

One difficulty associated with comparing results across studies is the lack of consensus when measuring outcomes. Across all ten studies identified in this review, 27 different outcome measures were used to assess the effectiveness of telerehabilitation. These included both performance-based assessments, such as psychometric testing, and subjective or patient-reported measures of health status, visual functioning and quality of life. In the four studies which used patient-reported outcomes, just one measure (SF-36) was used in more than one study. An important consideration for clinicians, researchers and trialists could be to aim for a more unified approach when deciding on a core set of outcome measures in future trials and evaluations of telerehabilitation. Secondly, whilst it is encouraging that patients' views and experiences are being considered when measuring the effectiveness of telerehabilitation, it is important to consider the sensitivity of outcome measures to meaningful changes in areas such as functionality, symptomatology, and quality-of-life etc. For example, the non-significant changes in quality-of-life observed in the study by Sabel and Gudlin [35] could be explained by the use of non-disease-specific measures, which may not be sufficiently sensitive to detect small or subtle changes in visual function [49]. Finally, the evidence synthesised in this review suggests that telerehabilitation is generally regarded as acceptable by those who are willing to engage with it. Yet, acceptability is a multifaceted concept which may not be fully explained by behaviour such as the degree of adherence or engagement with an intervention; thus, future studies investigating acceptability may benefit from a theoretical framework to guide the assessment of acceptability [50].

Although no studies were formally excluded on the basis of insufficient quality, some common study limitations were identified. The majority of the studies introduce a self-selection bias when participants elect to take part in research and are willing/show willingness to engage with telerehabilitation programmes. Although common in cross-sectional research, self-selection bias can complicate the interpretation of study data as participants' propensity for participating in research may correlate with the topic under investigation. For example, Lorenzini and Wittich [33] report that 79% of eligible participants declined to take part in the study. As such, the conclusions are based on a relatively small proportion of the target population. Reasons for non-participation were seldom discussed in the published reports; therefore, it is unclear whether factors such as level of familiarity with devices, visual functioning, extent of sight loss, or having assistance from a normally sighted friend or family member impact on engagement with telerehabilitation. In addition, study findings to date have evaluated telerehabilitation over a relatively short period of time. As observed by Lorenzini and Wittich [33], engagement is more likely to decrease after 6 months, highlighting the need for more longitudinal studies. A further common limitation was the relatively small sample sizes observed in the studies. For example, four of the 10 studies included in this review had a sample size of 10 or fewer. There are currently very few randomised controlled clinical trials evaluating patient outcomes in telerehabilitation, and we propose this would be an important avenue for further research.

This review's methodology has a number of limitations. Only articles written in English were screened and ultimately included, thus excluding potentially relevant studies in languages other than English. However, only three studies were excluded for this reason. Moreover, included studies were required to relate to some form of vision impairment, and several studies included heterogenous samples of varying or unknown degrees of sight loss from numerous conditions. A range of vision impairment terms were used across the studies including 'sight loss', 'blindness' and "low vision". Results were rarely disaggregated by disease severity or type, thereby making it difficult to account for potential nuances between different patient groups under the broad overarching term of 'vision impairment'. A key strength of this review was the inclusion of grey literature. Grey literature includes a range of documents not controlled by commercial publishing organisations and can be a rich source of information which cannot be obtained from other sources [51]. Our analysis of grey literature showed that after an initial switch to remote service delivery during the COVID-19 pandemic, many charities were reviewing their long-term rehabilitation frameworks with an indication that pathways will include a blended approach, offering both remote and face-to-face services on a personalised basis, but require further auditing and evaluation. It is notable that besides a few national sight loss charities (Blind Veterans UK, RNIB), the availability of telerehabilitation appeared to vary greatly, with availability appearing highest within local charities in areas including Cambridgeshire, Leicestershire, and Nottinghamshire. While a paucity of online documentation in other regions does not necessarily equate to an absence of such services, it does suggest a possible unevenness in their availability across local authorities. This may reflect broader issues pertaining to unequal access to sight loss support nationwide. As telerehabilitation continues to emerge as an effective and potentially permanent fixture in the care pathways of visually impaired people, there is a need to bridge the gaps in service delivery to ensure there is equitable provision across all areas of the UK, particularly given the potential for a wider geographical reach with remote services thereby increasing access to support.

In summary, the COVID-19 pandemic necessitated a redesign of traditional face-to-face rehabilitation pathways to remote service delivery. A previous systematic review assessing the effectiveness of low vision telerehabilitation found no studies had been completed in this area [22]. We identified a range of remote-based rehabilitation services aimed at optimising vision and encouraging adjustment to sight loss, with evidence to suggest some patients are generally accepting of this model and may benefit from improved functional and quality-of-life outcomes, whilst potentially offering a more cost-effective approach to continuing care. The weight of the evidence suggests telerehabilitation has a promising role in patient care pathways for people with a vision impairment; however, issues around long-term desirability and compliance remain unclear. Given the variability in patients' aptitude and motivation to sustainably engage with telerehabilitation, a self-select approach may be the most practical means of ensuring effective implementation of remote services. This review has addressed increasingly relevant questions about the role of telerehabilitation when applied among visually impaired people. The findings to date begin to illustrate the effectiveness of remote rehabilitation services, but more research is needed to better understand its scalability and longevity. Ultimately, we hope this review can inform key stakeholders, including hospital eye services, community groups, and charities about priority areas for future research and development.

Author contributions: All authors made substantial contributions to the design and analysis of the work. LJ and ML performed the literature search, article screening, data extraction, quality appraisal and manuscript preparation. CLC, NH, and RSMG conceptualised the review and edited the manuscript. All authors approved the final manuscript.

Competing interests: None

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Data availability statement: No data are available.

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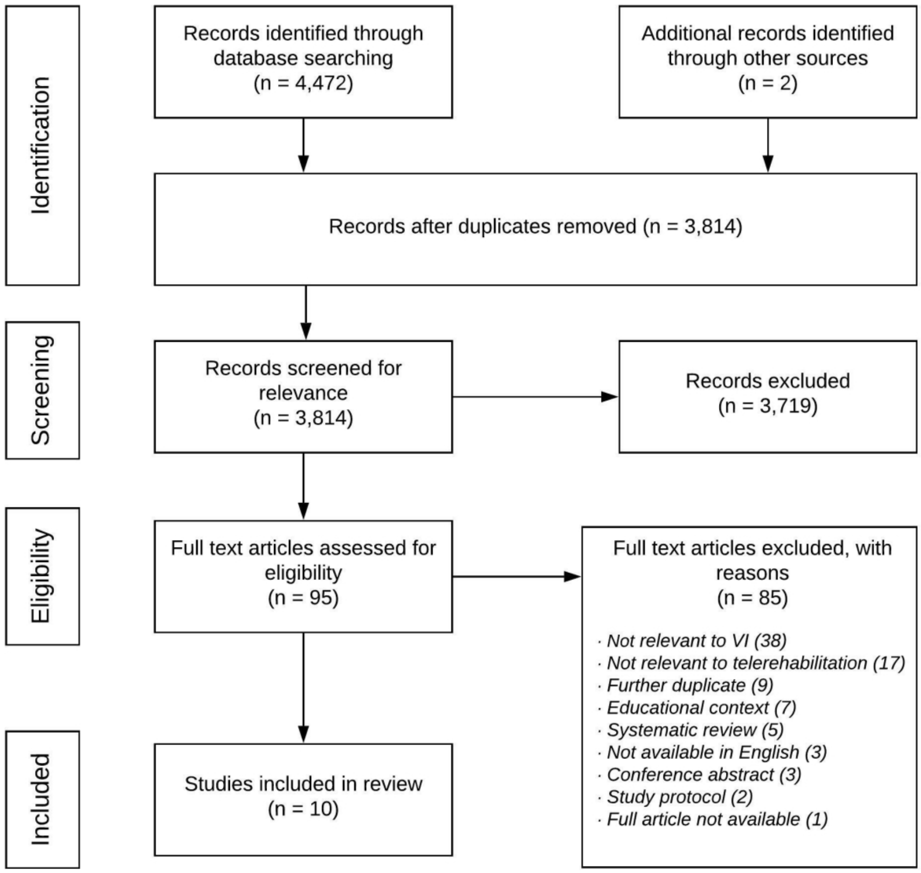

Figure 1. PRISMA diagram showing study selection process. Key: VI = vision impairment

170x159mm (300 x 300 DPI)

Supplementary material – Data extraction table

Authors	Study title	Design	Domain(s) of outcomes	Location	Study objectives	Study populations	Main results/conclusions
Bittner *et al*., 2018	Feasibility of telerehabilitation for low vision: satisfaction ratings by providers and patients	Experimental	Patient satisfaction and recommendations	USA	To develop, administer, refine and evaluate components required to deliver follow-up low vision telerehabilitation services.	10 participants with self-rated vision ranging from good to poor. 9 with AMD; 1 with DR. Average age 80 (range = 63-91) years.	Providers and participants rated video quality as excellent to good. Audio quality ratings were variable, generally related to signal strength or technical issues during some sessions. All participants agreed that they were satisfied and comfortable receiving telerehabilitation. Eight of 10 reported that their magnifier use improved. All except one reported that they were very interested in receiving telerehabilitation again. Positive feedback from both participants and providers in this pilot study supports the feasibility, acceptability, and potential value of low vision telerehabilitation.
Dogru-Huzmeli *et al*., 2021	Can diplopia complaint be reduced by telerehabilitation in multiple sclerosis patient during the pandemic? A case report	Case report	QoL and well-being	Turkey	To determine the effect of Cawthorne-Cooksey exercises applied via telerehabilitation on eye movements, vision, and quality of life in a multiple sclerosis patient with diplopia.	1 male participant with multiple sclerosis aged 39 years.	Following 4 months of telerehabilitation, the participant stated that his double vision complaints decreased, and his eyes could move more easily. When eye movements were evaluated, outward gaze restriction had improved. There was no change in visual acuity, anterior and posterior segment examinations, and OCT examination. It can be feasible to administer Cawthorne-Cooksey exercises using telerehabilitation to reduce diplopia.
Dunne *et al*., 2020	Maximizing telerehabilitation for patients with visual loss after stroke: interview and focus group study with stroke survivors, carers, and	Qualitative	Patient satisfaction and recommendations	UK	To identify barriers and facilitators using rehabilitation tools and elements of good practice in telerehabilitation among stroke survivors.	66 focus group participants. 32 stroke survivors with partial vision loss (18 men; aged 43-83 years, mean age 62.28 years), 10 carers (7 women; 41-75 years, mean age 54.70 years), and 24	Themes identified problems associated with poststroke health care from both patients' and occupational therapists' perspectives that need to be addressed to improve uptake of telerehabilitation. Themes included identifying additional materials or assistance to boost the impact of training packages. Perceptions of technology were considered a barrier

Authors	Study title	Design	Domain(s) of outcomes	Location	Study objectives	Study populations	Main results/conclusions
	occupational therapists					occupational therapists (19 women; 22-45 years, mean age 31.13 years)	by some but a facilitator by others. In addition, 4 key features of telerehabilitation were identified: additional materials, the importance of goal setting, repetition, and feedback.
Ihrig, 2019	Travel cost savings and practicality for low vision telerehabilitation	Cost analysis	Cost-effectiveness	USA	To evaluate patient acceptance and practicality of low vision telerehabilitation.	419 veterans, average age 83 (range =50-101) years. 406 were male. 208 had diagnosis that resulted in non-correctable or best corrected visual acuity in both eyes up to 20/150 (defined as not legally blind); 149 had non-correctable or best corrected visual acuity in both eyes of 20/200 or worse (defined as legal blindness); 22 had non-correctable peripheral visual field loss in one or both eyes >20 degrees (defined as not legally blind); and 40 had non-correctable peripheral visual field loss in both eyes <20 degrees (defined as legal blindness).	Of the 419 veterans seen since November 2012 (FY 13), the median saving of travel miles for rural patients was 122 miles per veteran (51,136 miles/419 veterans) and the median saving of travel time was 2.09 h per veteran (878 h/419 veterans). Overall, the median saving of the travel cost per rural individual (utilizing $0.535 per mile) was $65.29 per veteran ($27,357.76/419). Travel mileage and time saving resulted in an increase in access to low-vision rehabilitation (24% increase in partially sighted veterans evaluated in 5 years) by reducing the veteran's travel distance, time, and cost. Utilising low vision telerehabilitation increases early access and enables veterans who cannot travel to a specialty clinic the opportunity to prevent potential decline in functional ability over time.
Lancioni *et al.*, 2011	Enabling two women with blindness and additional disabilities to make phone calls independently via a	Case report	QoL and well-being	Italy	To assess whether two women with blindness and additional disabilities could make independent phone calls through a	Two female participants aged 30 and 41 years. One participant with retinopathy and congenital cataract leading to total blindness by age 28.	Both participants learnt to use the system and made phone calls independently to family members, friends and staff personnel. Neither participant made calls independently at baseline. During the first intervention phase, one participant had a mean cumulative conversation time per

Authors	Study title	Design	Domain(s) of outcomes	Location	Study objectives	Study populations	Main results/conclusions
	computer-aided telephone system				computer-aided telephone system.	One congenitally blind participant due to gestational complications.	session of ~11 minutes. The mean length of the sessions was ~21 minutes. For the second participant, mean (cumulative) conversation time per session was ~10 minutes. The mean length of the sessions was ~17 minutes.
Lorenzini & Wittich, 2021	Personalised telerehabilitation for a head-mounted low vision aid: A randomized feasibility study	Observational case-control	Patient satisfaction and recommendations	Canada	To determine the feasibility of telerehabilitation using eSight eyewear with low vision participants. Feasibility defined as achieving recruitment target, proportion of participants lost to follow up, and whether the intervention was accessible and acceptable.	57 participants; 58% male, average age 54.5 (range = 21-82) years. All were categorised as having an ocular disease, most common were optic nerve disease, AMD, RP, and retinopathy of prematurity.	Withdrawal rate was higher in the control group but did not differ significantly from the experimental group. High accessibility (93% of participants accessed the platform) and global acceptability (100% overall satisfaction) were reported among those who completed the telerehabilitation protocol. The therapist had no difficulty judging the participants' reading performances qualitatively while participants used their device to read their eSkills and VisExc guides. Most participants improved their daily activities, based on qualitative reports of the attained goals. Seventy-nine percent of individuals declined to participate, whereas 16% of participants decided not to use eSight Eyewear anymore. Positive feedback from the participants and the low vision therapist suggests the potential value of this modality for low vision services.
Lorenzini & Wittich, 2021	Head-mounted visual assistive technology–related quality of life changes after telerehabilitation	Observational case-control	Patient satisfaction and recommendations / QoL and well-being	Canada	To explore the effect of telerehabilitation (eSight eyewear) on quality-of-life and functional vision in individuals with low vision using a head-mounted display.	57 participants; 58% male, average age 54.5 (range = 21-82) years. All were categorised as having an ocular disease, most common were optic nerve disease, AMD, RP, and retinopathy of prematurity.	Assistive technology–related quality of life was improved when measured by the satisfaction scale but not the psychosocial scale within the first 3 months, independently of training type. Overall, functional vision improvement was observed within the first 2 weeks of device use and maintained during the 6-month study, independently of group type. eSight Eyewear, either with telerehabilitation or with the manufacturer

Authors	Study title	Design	Domain(s) of outcomes	Location	Study objectives	Study populations	Main results/conclusions
							self-training comparison, improved functional vision and increased users' quality of life within the initial 3 months of device training and practice.
Sabel & Gudlin, 2014	Vision restoration training for glaucoma: A randomized clinical trial	Randomised clinical trial	Vision training / QoL and well-being	Germany	To determine if behavioural activation of areas of residual vision using daily 1-hour vision restoration training for glaucoma for 3-months improves detection accuracy compared with placebo.	30 participants; 14 male; mean [SD] age 61.7 [10.1] years; 20 participants with primary open angle glaucoma; 5 with normal tension glaucoma; 4 with secondary glaucoma; 1 with angle-closure glaucoma. Mean [SD] visual acuity was 0.62 [0.34] (range 0.0-1.3 logMAR) in the right eye and 0.76 [0.40] (range 0.0-1.8 logMAR) in the left eye.	Vision restoration training for glaucoma led to significant detection accuracy gains in high-resolution perimetry (P = .007), which were not found with white-on-white or blue-on-yellow perimetry. Pre-post differences after vision restoration training for glaucoma were greater compared with placebo in all perimetry tests (P = .02 for high-resolution perimetry, P = .04 for white on white, and P = .04 for blue on yellow), and these results were independent of eye movements. Vision restoration training for glaucoma (but not placebo) also led to faster reaction time (P = .009). Vision-related quality of life was unaffected, but the health-related quality-of-life mental health domain increased in both groups.
Senjam *et al.*, 2021	Tele-rehabilitation for visually challenged students during COVID-19 pandemic: Lesson learned	Case report	Managing symptoms	India	To report experiences of a telerehabilitation service available primarily for students with visual disabilities amidst the COVID-19 pandemic.	492 participants; male = 388. The majority of beneficiaries were between 11 and 30 years (82.3%). Around 96% of beneficiaries were visually disabled, and 16.5% had unknown visual status (waiting or applied for certificates).	The most common ocular complaints for which beneficiaries required advice were itching (N= 121; 36.1%); watering eyes (N = 54; 16.1%); painful eyes (N = 12; 3.6%), redness (N = 5; 1.5%). Telerehabilitation can offer a safe and efficient means of providing reliable information to visually impaired individuals.

Authors	Study title	Design	Domain(s) of outcomes	Location	Study objectives	Study populations	Main results/conclusions
Tinelli *et al.*, 2017	Development and implementation of a new telerehabilitation system for audio-visual stimulation training in hemianopia	Experimental	Vision training	Italy	To test the feasibility and efficacy of audio-visual telerehabilitation in three adult patients with chronic visual field defects.	Three participants with hemianopia. One male had cerebral stroke; one adult had drug-resistant epilepsy caused by a focal cortical dysplasia type 2a; one male had partial left homonymous hemianopia following surgery for a meningioma in the right hemisphere.	Results suggest audio-visual telerehabilitation is an effective treatment based on the stimulation of ocular movements and visual exploration functions through compensative strategies. Patients were instructed to use saccadic eye movements for the detection of visual targets and thus they showed, at the end of the treatment, an activation of the oculomotor system and a change in responsiveness toward visual stimuli, confirmed by behavioural data, mostly using the Unimodal Visual Test. The test allows patients to exercise independently in a familiar context, while under remote supervision. It may give the patient a sense of control and autonomy, which can contribute to a better therapy outcome, also reducing the need for one-to-one treatment time and home visits.

Supplementary material – Data extraction table. Data extraction table. **Key** - QoL: quality-of-life. AMD: age-related macular degeneration. DR: diabetic retinopathy. RP: retinitis pigmentosa. SD: standard deviation. logMAR: logarithm of the minimum angle of resolution. OCT: optical coherence tomography. FY: fiscal year.

Reporting checklist for systematic review (with or without a meta-analysis).

Based on the PRISMA guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

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		Reporting Item	Page Number
Title			
Title	#1	Identify the report as a systematic review	1
Abstract			

Abstract	#2	Report an abstract addressing each item in the PRISMA 2020 for Abstracts checklist	2
Introduction			
Background/rationale	#3	Describe the rationale for the review in the context of existing knowledge	4
Objectives	#4	Provide an explicit statement of the objective(s) or question(s) the review addresses	5
Methods			
Eligibility criteria	#5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses	7
Information sources	#6	Specify all databases, registers, websites, organisations, reference lists, and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted	6
Search strategy	#7	Present the full search strategies for all databases, registers, and websites, including any filters and limits used	6
Selection process	#8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they	7

		worked independently, and, if applicable, details of automation tools used in the process	
Data collection process	#9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and, if applicable, details of automation tools used in the process	7
Data items	#10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (for example, for all measures, time points, analyses), and, if not, the methods used to decide which results to collect	Supplementary material
Study risk of bias assessment	#11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and, if applicable, details of automation tools used in the process	8
Effect measures	#12	Specify for each outcome the effect measure(s) (such as risk ratio, mean difference) used in the synthesis or presentation of results	N/A

Synthesis methods	#13a	Describe the processes used to decide which studies were eligible for each synthesis (such as tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5))	8
Synthesis methods	#13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics or data conversions	N/A
Synthesis methods	#13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses	Supplementary material
Synthesis methods	#13d	Describe any methods used to synthesise results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used	N/A
Synthesis methods	#13e	Describe any methods used to explore possible causes of heterogeneity among study results (such as subgroup analysis, meta-regression)	N/A
Synthesis methods	#13f	Describe any sensitivity analyses conducted to assess robustness of the synthesised results	N/A

Reporting bias assessment	#14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases)	6
Certainty assessment	#15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome	7
Data items	#10b	List and define all other variables for which data were sought (such as participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information	Supplementary material
Results			
Study selection	#16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram (http://www.prisma-statement.org/PRISMAStatement/FlowDiagram)	8
Study selection	#16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded	8
Study characteristics	#17	Cite each included study and present its characteristics	9-15 + Supplementary material

Risk of bias in studies	#18	Present assessments of risk of bias for each included study	8
Results of individual studies	#19	For all outcomes, present for each study (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (such as confidence/credible interval), ideally using structured tables or plots	N/A
Results of syntheses	#20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies	8
Results of syntheses	#20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (such as confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect	N/A
Results of syntheses	#20c	Present results of all investigations of possible causes of heterogeneity among study results	N/A
Results of syntheses	#20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesised results	N/A

Risk of reporting biases in syntheses	#21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed	N/A
Certainty of evidence	#22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed	16-20
Discussion			
Results in context	#23a	Provide a general interpretation of the results in the context of other evidence	16-20
Limitations of included studies	#23b	Discuss any limitations of the evidence included in the review	18
Limitations of the review methods	#23c	Discuss any limitations of the review processes used	19
Implications	#23d	Discuss implications of the results for practice, policy, and future research	16-20
Other information			
Registration and protocol	#24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered	7
Registration and protocol	#24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared	7

Registration and protocol	#24c	Describe and explain any amendments to information provided at registration or in the protocol	N/A
Support	#25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review	20
Competing interests	#26	Declare any competing interests of review authors	20
Availability of data, code, and other materials	#27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review	20

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A scoping review of remote rehabilitation (telerehabilitation) services to support people with vision impairment.

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Title: A scoping review of remote rehabilitation (telerehabilitation) services to support people with vision impairment.

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ABSTRACT

Objective: Telerehabilitation for individuals with vision impairment aims to maintain maximum physical and/or psychological functioning through remote service delivery. This review aims to describe the type of telerehabilitation services available to people with vision impairment and summarise evidence on health-related outcomes, well-being and cost-effectiveness.

Design: Scoping review.

Data sources: CINAHL Plus, MEDLINE, PsycARTICLES, PsychINFO, Embase, PubMed, HMIC and Ovid Emcare were searched, without date restrictions up to 24 May 2021. Charity and government websites, conference proceedings, and clinical trial databases were also examined.

Eligibility criteria: Eligible studies evaluated benefits of telerehabilitation services for adults with vision impairment. Studies were excluded if they were not available in English, or focused on distance learning of visually impaired students.

Data extraction and synthesis: Two independent reviewers screened articles and extracted data. A risk of bias analysis was performed.

Outcome measures: Measures of benefit included performance-based assessment, patient-reported outcomes, and cost-effectiveness.

Results: Of 4,472 articles, 10 eligible studies were included. Outcomes addressed patient satisfaction (n=4;33.3%), quality-of-life, activities of daily living, and well-being (n=4;33.3%), objective visual function (n=2;16.6%), and knowledge relating to ocular symptoms (n=1;8.3%). Two studies addressed multiple outcomes. Cost-effectiveness was addressed in one article (8.3%). Patients were generally satisfied with their experiences, which had a range of positive benefits on functional and quality-of-life outcomes in areas relating to daily activities (e.g., reading, making phone calls). Telerehabilitation allowed patients to undertake vision optimisation training to prevent vision deterioration. Grey literature indicated there are no completed clinical trials relating to low vision telerehabilitation. Charity services had implemented digital skills training to help beneficiaries communicate remotely.

Conclusion: While acceptability of telerehabilitation was mostly high, limited real-world data are available which raises questions around the long-term desirability of

this Further trials are needed to evaluate telerehabilitation using a robust set of outcome measures.

PROSPERO registration number: CRD42021254825

Strengths and limitations of this study

- This review provides novel findings informing design of future trials and evaluations of telerehabilitation.
- Inclusion of grey literature reduces publication bias and increases the comprehensiveness of the review.
- Only articles written in English were included and results were seldom disaggregated by disease type or severity.

INTRODUCTION

Visual impairment is a broad term used to describe a reduction in visual sensitivity that cannot be corrected by standard eyeglasses or medical treatment. It is estimated that over 2 million people in the United Kingdom (UK) are living with a form of visual impairment [(1)]. People with vision impairment may be classified as 'sight impaired' (i.e., partially sighted) or 'severely sight impaired' (i.e., legally blind) [(2)]. The impact of visual impairment can be complex and highly heterogenous, affecting aspects of daily functioning, mobility, and quality of life [(3-8)]. Among the widely prevalent ophthalmic conditions such as age-related macular degeneration, glaucoma, and diabetic retinopathy, loss of vision is typically progressive and irreversible; hence, support relies heavily on rehabilitation to promote adaption, enabling patients to better manage the challenges associated with vision loss and to live an independent and fulfilling life [(9, 10)].

The mainstay of rehabilitation is to restore or maintain physical and/or psychological functioning to the maximum degree possible in individuals living with disease or injury [(11)]. In vision rehabilitation, eye care providers are encouraged to provide rehabilitative support or refer patients to relevant services, even in cases of mild or moderate sight loss [(12)]. Rehabilitation encompasses many disciplines, and interventions may include provision of visual aids, devices and software, behavioural training, home environment assessments and adaptions, social and psychological support, leisure and vocational activities, or a combination of these strategies [(13, 14)]. However, rehabilitation is characteristically structured around overcoming the practical and functional challenges of sight loss, whilst psychological outcomes are seldom addressed directly [(15)]. The type of services which are offered often depends on the nature of the visual impairment. For example, the rehabilitative needs of individuals with central visual field loss may differ from those with impaired peripheral vision [(16)]. The traditional mode of delivery for vision rehabilitation has been in face-to-face settings within outpatient clinics or home visits by low vision specialists or allied health professionals; though digital developments have increased opportunity for remote service delivery (i.e., telerehabilitation).

Telerehabilitation, also known as virtual training, refers to delivering rehabilitative services using a remote or virtual approach, facilitated by telecommunication technologies. Services may comprise a range of elements designed to assess, prevent, treat, educate, or counsel individuals living with chronic health conditions [17]. Telerehabilitation services may be synchronous, whereby services are delivered in real-time using two-way video or audio communication, or asynchronous, such as remote evaluation of recorded videos or other measurements such as surveys or psychophysical testing [18]. Compared to traditional face-to-face rehabilitation, telerehabilitation offers potential benefits, such as reduced costs, increased geographical accessibility, and creating opportunities to extend limited resources [19]. Moreover, telerehabilitation has been identified as an effective means of delivering support to individuals with chronic conditions including multiple sclerosis, osteoarthritis, and stroke [20-22].

Whilst there is convincing evidence to suggest telerehabilitation can be effective at improving physical and psychological functioning in people living with chronic health conditions [20-22], less is known about the benefits of telerehabilitation services for people with a vision impairment. For example, a previous systematic review sought to compare outcomes between face-to-face and virtual vision rehabilitation services, yet no completed studies were found [23]. Additionally, new services such as remote delivery of clinical care (telehealth) are likely to have emerged during the COVID-19 pandemic which have yet to be reviewed. This is significant given the rapid and extensive scale-up of telehealth services since the beginning of the pandemic [24, 25]. This scoping review, therefore, aims to draw together evidence on telerehabilitation services, and describe their impact on health and well-being outcomes in people with vision impairment.

Objectives

1. Describe the type of telerehabilitation services available to people with vision impairment.
2. Provide insight on the impact of telerehabilitation in terms of health-related outcomes, well-being and cost-effectiveness.

METHODS

This review follows best practice for conducting scoping reviews as outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for Scoping Reviews checklist to ensure all aspects of the process are undertaken using rigorous and transparent methods [26]. A search of the electronic databases CINAHL Plus and MEDLINE (via EBSCOhost) and PsycARTICLES, PsychINFO, Embase, PubMed, HMIC and Ovid Emcare (via Ovid) was undertaken without date restrictions or topic filters. As recommended by The Cochrane Handbook for Systematic Reviews of Interventions, medical subject headings (MeSH) were used to identify the most relevant articles [27]. MeSH terms are official words or phrases selected to represent medical concepts and are assigned to articles in order to describe what the research item is about [28]. This process provided a list of keywords relating to vision impairment and telerehabilitation. For detailed search terms, see Table 1. Reference lists of included studies and any identified systematic reviews were also reviewed for relevant articles, and citation tracking was performed using Google Scholar.

Vision impairment term		Telerehabilitation term
vision OR low vision OR vision loss OR reduced vision OR subnormal vision OR diminished vision OR vis* impair* OR sight loss OR blind* OR partially sighted	AND	telerehab* OR tele-rehab* OR remote rehab* OR virtual rehab* OR e-learning OR online learning OR online training OR telephone training OR telephone rehab* OR telephone learning OR virtual learning OR web training OR virtual training

Table 1. Search terms

In addition, we reviewed online conference proceedings for relevant abstracts by searching the websites of the International Society of Physical and Rehabilitation Medicine; American Congress of Rehabilitation Medicine; Association for Research in Vision and Ophthalmology; American Academy of Ophthalmology; European Association for Vision and Eye Research. A search of grey literature included searching for relevant articles or reports on the websites of organisations such as the UK National Institute for Health and Clinical Excellence (NICE; www.nice.org.uk) and

National Health Service (NHS) Evidence (www.evidence.nhs.uk). World Health Organisation International Clinical Trials Registry Platform (ICTRP) and the US National Institute of Health trial register (ClinicalTrials.gov) were searched for ongoing and completed trials relating to vision impairment and telerehabilitation. We also conducted an extensive search of the UK Charity Commission website to identify organisations with links to vision impairment and rehabilitation. Relevant charity websites were then searched and in cases where telerehabilitation was documented, any available documentation was downloaded and reviewed, and charities were contacted to enquire about the current status of telerehabilitation.

Population

Adult patients (aged 18 years or older) with visual impairment caused by any underlying condition, medical or non-medical trauma.

Intervention

The scoping review considered how telerehabilitation services have impacted people with vision impairment. Where available, evidence on cost-effectiveness will be included. The review included studies where a telerehabilitation service is delivered and evaluated, which could relate to improving well-being; increased social participation/connectivity; maintaining activities of daily living (e.g., mobility); optimisation of vision.

Articles written in English, with no restrictions on publication period, and only where the full text was available were included. Studies were required to address the intervention (telerehabilitation) and population of interest (adults with visual impairment). Articles were excluded if they did not relate to remote service delivery (i.e., face-to-face services). Articles focusing only on an educational context (e.g., e-learning) were also excluded. For example, visually impaired students using home technology for distance learning.

Two authors (LJ and ML) independently screened studies using Covidence systematic review software (Veritas Health Innovation Ltd, Melbourne, Australia; available at www.covidence.org) to assess eligibility. Any disagreement in coding decisions were resolved through discussion. Relevant information (e.g., publication details, characteristics of participants, study design, outcomes measured, study results, and conclusions) from eligible articles was entered into a data extraction table.

Studies were assessed for quality using Kmet *et al.* '*Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields'* [29]. This quality appraisal tool was chosen because of both quantitative and qualitative studies emerging from the literature search. The tool uses a checklist to provide guidance on study aspects which should be considered when making a decision regarding quality of reporting. For example, in response to the item regarding subject characteristics, the study in question must provide at least the age and sex of participants. This review is registered online with the International prospective register of systematic reviews (PROSPERO; www.crd.york.ac.uk/prospero/; Reference CRD42021254825).

Patient and public involvement

No patients were involved in the design of the review. We will disseminate plain language summaries to relevant patient groups including beneficiaries of Blind Veterans UK.

Research ethics approval

Ethical approval for this scoping review was not required.

RESULTS

Searches were run on 24 May 2021 and yielded 4,472 results. Of these, 658 were automatically removed as duplicates. This left 3,814 studies to screen using title and abstract, of which 3,719 were excluded and 95 were assessed for full-text eligibility. Studies were mostly excluded at the title and abstract screening stage because they did not relate to telerehabilitation or did not involve people with a vision impairment. These two reasons were also the primary cause for exclusion in the full-text review accounting for 17 and 38 exclusions, respectively. A further two studies were added through reference list searching. Ultimately, 10 full-text studies were selected for inclusion. The study selection process is shown in the PRISMA diagram in Figure 1.

<Insert Figure 1 here>

Figure 1. PRISMA diagram showing study selection process. Key: VI = vision impairment

Two authors (LJ and ML) independently assessed the quality of all 10 studies. The lowest score was 0.64, the highest was 1.00 (i.e., all responses to relevant questions in the Kmet *et al*. appraisal criteria were 'Yes'), and the median score was 0.93. Full details of quality appraisal are provided in Supplementary Material 1.

The following overview of study findings is organised according to the main outcome domains for each of the 10 articles identified in the literature search. Two articles feature in more than one section as the outcomes were translatable across multiple domains. Four studies (33.3%) addressed patient satisfaction[(30, 31, 32, 33)], two studies (16.6%) related to objective visual function [(34, 35)], four studies (33.3%) measured patient-reported outcomes, activities of daily living, and well-being [(33, 34, 36, 37)], one study (8.3%) addressed knowledge relating to ocular symptoms [(38)], and a further one study (8.3%) was an analysis of cost-effectiveness [(39)]. Six studies used a synchronous modality whereas four studies were asynchronous in nature. For full details of the included studies, refer to the data extraction table (Supplementary Material 2).

Patient satisfaction

Four articles explored patients' satisfaction with telerehabilitation which led to recommendations for key features to improve uptake of services. Three of these articles reported the findings of feasibility studies [31, 32, 33], and one was a qualitative analysis of patient experiences [30]. All of these studies included participants with a visual impairment caused by a range of pathologies including age-related macular degeneration, optic nerve disease, retinitis pigmentosa, and stroke-related visual field deficit.

Dunne *et al.*'s [30] study of stroke survivors reports the outcomes of qualitative interviews and focus groups with patients and carers. The study was informed by the findings of a survey of Stroke Association group members in the UK and the aims were to understand experiences of a compensatory eye-movement tool and training packages. The Durham Reading and Exploration Training (DREX) is a computer-based telerehabilitation training system teaching adaptive eye movement strategies to enable stroke survivors to cope more effectively with visual field deficits [40]. DREX is a mobile application which incorporates tasks that combine both reading and exploration (e.g., scanning an array to locate a target). In the context of rehabilitation, the application is asynchronous in nature whereby healthcare professionals can access and review patients' results at a later time through a clinical portal. The wider study required patients with stroke-related visual field defects to complete the DREX trials on a tablet in their own homes and outcomes were compared to a control intervention, which consisted of attention-based tasks with no eye movement or exploration exercises. Significantly greater gains were observed in visual exploration (12.9%, 95% confidence interval [CI] = 8.4 to 17.3%) and reading (18.5%, 95% CI = 9.9 to 27.0%) following DREX than in the control intervention for both tasks, respectively (exploration = 4.8%, 95% CI = 0.1 to 9.5%; reading = 1.6%, 95% CI = −4.8 to 8.7%) [40]. Qualitative responses highlighted a range of issues in the application of telerehabilitation for visually impaired stroke survivors. For example, a lack of confidence with technology, perceived fear of making mistakes while online, distrust of the quality of the intervention, and concerns with reduced face-to-face contact. However, these issues could be addressed in initial in-person visits to alleviate concerns and facilitate engagement and motivation in the rehabilitation process. One challenge is that compensatory training is inherently repetitive in nature; thus, measures should be taken to ensure telerehabilitation tools remain accessible and stimulating to avoid disengagement. The authors propose that one approach which may obviate disengagement is to employ feedback and goal setting to improve motivation and provide tangible progress updates.

Patient satisfaction was assessed by Bittner *et al*. [31] in a pilot study to develop, administer and evaluate a synchronous virtual low vision portal providing telerehabilitation services. Ten patients diagnosed with either age-related macular degeneration (n = 9) or diabetic retinopathy (n = 1) were enrolled. Participants were required to have access to a home telephone to use the Internet-based video conference portal. Tablet devices were provided as well as MiFi (wireless router which acts as a mobile Wi-Fi hotspot) to enable connection to the Internet. Each participant received one telerehabilitation session which lasted approximately one hour. The session included administration of the MNREAD chart which consists of a series of 60-character sentences displayed over three lines and is used to assess reading fluency and proficiency using optical magnifiers, using video and audio recordings of the participant. Assessments of working distance and lighting were made by the provider viewing the video of the participant reading with their magnifier, whereas assessments of reading speed and accuracy relied on the audio component as participants read aloud during the MNREAD and near acuity tests. The outcomes were participants' and providers' audio and video quality ratings. Video quality was rated as excellent to good, whereas audio ratings were more variable. All participants were satisfied and comfortable receiving telerehabilitation and evaluation via videoconferencing. Eight of 10 reported that their magnifier use improved after telerehabilitation. All except one reported that they were very interested in receiving telerehabilitation services again if their visual needs changed.

Lorenzini and Wittich [32] reported outcomes related to patient satisfaction in a randomised feasibility study using a head-mounted display and a telehealth platform to deliver synchronous telerehabilitation sessions at home. Participants received real-time distance training sessions delivered by a low vision therapist. The intervention focused on the functional aspects of using eSight eyewear, an assistive technology designed to maximise visual input and compensate for vision loss. The intervention group underwent a personalised training programme including eSkills functional learning activities such as reading, writing, and distance vision training. A control group were randomly allocated to conventional eSight self-training using the eSkills user guide. Fifty-seven visually impaired participants were enrolled (experimental group, n = 28), the most common causes of sight loss were optic nerve disease, age-related macular degeneration, retinopathy of prematurity, and retinitis pigmentosa. Retention rates during the study were 93% (n = 53) at 2 weeks, 68% (n = 39) at 3 months, and 65% (n = 37) at 6 months. A higher proportion of patients who withdrew from the study were enrolled into the control group. Participants reported being comfortable with receiving telerehabilitation training at home, with 16 of 23 (66%) agreeing the programme was effective and efficient, and the majority (20 of 23) approving that they would be interested in using telerehabilitation again in the future.

A parallel investigation by Lorenzini and Wittich [33] used standardised measures to assess quality of life and patient satisfaction following the eSight telerehabilitation programme. Quality of life outcomes are reported in a later section. Satisfaction was measured using the 12-item Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST) tool [41]. Scores on the measure increased for participants in both the experimental and control group between baseline and 3-months of device usage, suggesting satisfaction improved independently of the type of training. There were no differences in assistive technology-related satisfaction based on age or sex. Improvement in QUEST scores were not maintained at 6-months. The authors suggest this may be due to the device no longer meeting certain needs after extended usage, or a lessening impact of social desirability, leading to more realistic and honest responses from participants over time.

Objective visual function

Two studies focused on training related to optimisation of vision delivered through a telerehabilitation service. The studies used visual exploration and ocular movement tasks to activate neuroplasticity to compensate for visual loss. Both studies included patients with measurable visual field loss including areas of diminished sensitivity in glaucoma and hemianopia in stroke patients.

Sabel and Gudlin [34] compared outcomes of asynchronous behavioural training using a 1-hour computer-based vision restoration programme for people with glaucoma and a placebo group. Participants were required to have a stable glaucomatous visual field defect inside 30° eccentricity in at least one eye, with well controlled intraocular pressure. After baseline assessments, training was performed 6-days per week for 3-months at home on a commercially available computer with adaptive parameter adjustments. The experimental group performed vision training similar to perimetry whereby visual stimuli of varying luminance are presented in areas of residual vision. The placebo group performed stimulus discrimination training. Vision restoration exercises led to improved vision-related performance in detection accuracy as determined by high-resolution perimetry (p=0.007). Pre versus post differences after vision training for glaucoma were greater compared with placebo in all perimetry tests (p=0.02 for high-resolution perimetry; p=0.04 for white-on-white perimetry; p=0.04 for blue on yellow perimetry), without affecting eye movements. Moreover, the vision restoration training led to faster reaction time for the glaucoma group (p=0.009). The authors conclude that a telerehabilitation system designed to promote visual system plasticity can be used among older age adults despite widespread visual deterioration, and activation of residual vision may partly reverse vision loss.

A study on patients with hemianopia used a bespoke asynchronous audio-visual telerehabilitation system [35]. The system featured a semi-circular apparatus in which visual and acoustic stimuli are presented and a central camera to control head and eye movements. Patients used the system at home on a customised tablet which was controlled by a hospital-based therapist. Following an initial assessment in the clinic, participants underwent training at home at least 5 days a week for up to 12 months. The aim of the training was to stimulate multisensory integration mechanisms to reinforce visual and spatial compensatory functions, for example, adoption of oculomotor strategies. Among the sample of three adults with hemianopia, all were capable of actively using the device independently whilst under remote supervision. Participants showed some improvements in visual detection abilities, which was assessed using two procedures (a unimodal test using only visual stimuli presented at one of 12 spatial locations lasting 100 milliseconds, and a bimodal audio-visual test whereby visual stimuli was paired with sound), with the strongest effect on both testing procedures observed when participants were free to use eye movements to detect targets, rather than the fixed eye condition.

Quality-of-life, activities of daily living, and well-being

Four articles assessed outcomes relating to quality-of-life, activities of daily living, and well-being following telerehabilitation [33, 34, 36, 37]. The studies use patient-reported outcome measures and behavioural measurements to examine the benefits of remote interventions in people with a vision impairment. Two articles are case reports [36, 37], and two articles describe the quality-of-life outcomes from the eSight eyewear [33], and vision restoration training programmes [34], described in an earlier section.

Lorenzini and Wittich [33] measure changes in quality-of-life following telerehabilitation with the eSight eyewear programme using the Psychosocial Impact of Assistive Devices Scale (PIADS) [42], a 26-item questionnaire composed of three subscales (competence, adaptability, and self-esteem), and the Veterans Affairs Low Vision Visual Functioning Questionnaire (VA LV VFQ-48) [43], a 48-item instrument used to measuresubjective visual outcomes. Visually impaired participants completed the measures at baseline, 2-weeks, 3-months, and 6-months. Results patterns were similar across the three subscales of the PIADS showing statistically significantly improved scores after 3 months in both the intervention and control groups ($p=0.05$), indicating that assistive technology-related quality-of-life (i.e., perceived impact of assistive devices on quality-of-life) improved independently of the type of training received. Self-reported functional vision outcomes, as determined by the VA LV VFQ-48, yielded statistically significant improvements in overall scores, as well as in subscales (reading ($p=0.03$), visual information ($p=<0.001$), mobility (<0.001)) after 2 weeks of using the device; improvements also continued after 3 months (all $p = \leq 0.05$).

Sabel and Gudlin's [34] vision restoration programme used the National Eye Institute Visual Function Questionnaire (NEI-VFQ-25) [44] and the Short-Form-36 (SF-36) [45] to measure changes in quality of life between baseline and post-intervention follow-up. Vision training was not associated with robust changes on these measures. Only the mental health subscale of the SF-36 was found to have improved, which may be caused by non-specific training effects such as attention, alertness, or expectation. However, participants had generally scored highly on both measures at baseline, indicating few everyday vision deficits.

A case report by Dogru-Huzmeli *et al*. [36] explored whether diplopia complaints could be ameliorated using the Cawthorne-Cooksey exercises applied via telerehabilitation in a multiple sclerosis patient with a visual field scotoma. Cawthorne-

Cooksey exercises use a set of eye and head movements which are based on the concept of habituation and designed to build up a tolerance mechanism to support equilibrium and balance [46, 47]. Exercises were delivered synchronously through WhatsApp video calls over 30 sessions. Comparison of pre- and post- eye examinations suggested gaze restriction, as determined through ophthalmic examination, had improved and that the patient had fewer self-reported double vision complaints. Pre- and post-intervention quality-of-life was assessed using the SF-36 measure of general health. Analysis was based on descriptive reporting of changes in scores, with no statistical analysis reported. The authors report improvement in all domains of the SF-36, except for physical functioning, where there was no change.

A study from Lancioni and colleagues [37] assessed whether two congenitally blind women could be supported to make independent phone calls using a computer-aided system. Both women attended a rehabilitation centre where the study took place. The system comprised of a netbook computer which was enabled with a global system for mobile communication with a headset and microphone apparatus. The study adopted an ABAB design in which A represented baseline phases and B represented intervention phases with the telephone system. Communication-related outcomes included the total number of calls made, number of calls met with a response, and length of calls. Both participants learnt to use the system and made phone calls independently to a variety of contacts such as family members, friends, and care staff personnel, indicating that the intervention may be useful for enabling people with a vision impairment to manage phone calls on their own.

Knowledge relating to ocular symptoms

One study used a telerehabilitation approach to increase knowledge of ocular symptoms to support patients attending a residential school for visually impaired people during the COVID-19 pandemic [38]. Senjam and colleagues [38] used voice-over internet protocols (e.g., WhatsApp calling, Zoom) to enable rehabilitation practitioners at a tertiary eye centre in India to deliver therapeutic education and counselling interventions and monitor ocular complaints among visually impaired adults and children who were unable to attend face-to-face appointments. Over a 2-month study period, 492 patients contacted the team. Health-related complaints were made by 335 patients, the most common ocular complaints being itching (36.1%), watering (16.1%), and painful eyes (3.6%). Counselling sessions addressed uncertainty surrounding clinical monitoring of eye health, however specific outcomes of counselling were not reported.

Cost-effectiveness

A retrospective cost analysis from Ihrig [39] examined the economic practicality of a clinical model of telerehabilitation for visually impaired military veterans. Telerehabilitation was delivered by an optometrist and rehabilitation therapist to veterans with conditions including age-related macular degeneration, glaucoma, diabetic retinopathy, cataracts, and retinitis pigmentosa. Sessions took place remotely at either the participants' home or local community outpatient centre. The rehabilitation intervention included home adaptive skills training, which includes a home safety checklist, orientation and mobility training and computer training, as well as training with vision-related activities such as meal management, financial planning, personal care, and leisure time activities (Ihrig, 2014) [48]. Total and median travel cost and time savings were estimated per veteran per fiscal year. Introduction of the telerehabilitation service in 2012 increased access to rural veterans in Western New York. Over a 5-year period, 419 veterans who were unable to access traditional low vision rehabilitation due to travel issues accessed the remote service. The proportion of patients accessing the telerehabilitation service represented 24% of the overall rehabilitation caseload. Median saving of travel miles was 122 miles per veteran (51,136 miles/419 veterans). Median saving of travel time was 2.09 hours per veteran (878 hours/419 veterans). Overall, median travel cost saving per rural individual was $65.29 per veteran ($27,357.76/419 veterans). The authors conclude that telerehabilitation can be a practical, time-saving, and cost-saving alternative to traditional face-to-face consultations.

Grey literature

Searches of charity websites led to the identification of 11 organisations in the UK where vision rehabilitation services had been shifted to remote delivery during the pandemic. The full list of organisations and the type of service delivery are described in Supplementary Material 3. The charities were contacted about telerehabilitation services and whether any evaluations had been undertaken. This process resulted in the review of seven documents, predominantly internal reports about the restructure of rehabilitation services during the COVID-19 pandemic. While these documents were mostly descriptive, there was useful information demonstrating telerehabilitation practice patterns in the third sector. Analysis of grey literature showed that many charities were reviewing their long-term rehabilitation frameworks with an indication that pathways will include a blended approach, offering both remote and face-to-face services on a personalised basis, but require further auditing and evaluation. Most of the organisations described implementing digital skills training to enable beneficiaries to become more proficient with computers and technology, such as making video calls and downloading smartphone applications. There were also examples of internal service evaluations to identify preferences in rehabilitation delivery. For example, Blind Veterans UK, a charity providing support and services to visually impaired UK veterans, reported information about the needs of their beneficiaries (including emotional support, befriending, assistance with shopping and using technology), methods in delivering remote rehabilitation (including 1:1 interventions such as mindfulness phone sessions and video-based group exercises), and working with allied agencies throughout the COVID-19 pandemic to signpost beneficiaries to support. It was notable that besides a few national sight loss charities (Blind Veterans UK, RNIB), the availability of telerehabilitation appeared to vary greatly, appearing highest within local charities in areas including Cambridgeshire, Leicestershire, and Nottinghamshire.

The search of clinical trial databases returned two ongoing trials relevant to telerehabilitation for visually impaired people, which are briefly described here. Van der Aa and colleagues (Trial ID: NTR6337) will examine the feasibility of an e-mental health treatment for patients with retinal exudative diseases receiving anti-VEGF treatment. The cognitive behavioural therapy-based intervention is offered via the Internet through the guidance of a social worker. The trial will deliver training and information which aim to help patients in dealing with their eye condition and managing uncertainties around treatment. The primary outcomes relate to measurements of depression, anxiety, and quality of life. Another trial (NCT04926974) will evaluate the efficacy of a mobile phone application to improve quality of life in older adults with low vision. The application features include real-time remote personal assistance with visual tasks, optical character recognition which allows text to be converted to audio and read aloud, and magnifiers to aid vision. The study seeks to understand the potential of these technologies to improve daily activities, community participation, independence, and self-sufficiency in people with low vision. Notably, there are a range of ongoing or completed trials relating to telemonitoring of visually impaired people, such as validation of home-based measurement tools (e.g., remote visual field testing). Given such studies are intended to address the broader concept of home monitoring and are not specifically within the context of rehabilitation, these trials were not included.

Trends in publishing

As shown by the results of this review, studies evaluating the impact of telerehabilitation on people with vision impairment are beginning to emerge among the published literature. Yet, these studies represent only a small proportion of the total research on people with vision impairment. For example, a PubMed search for articles with 'vision impairment' or 'blindness' in the title or abstract yielded 17,783 results since 2010 alone; while in that same period just 10 articles (0.06%) were published that were relevant to telerehabilitation.

DISCUSSION

Vision rehabilitation is a key stage in the eye care journey. Rehabilitative services can help to mitigate the impact of vision loss by equipping patients with new skills and training while providing social connectedness and psychological support [(49-53)]. This review shows that the landscape of rehabilitation is evolving to include synchronous and asynchronous approaches to remote rehabilitation for people with eye conditions. Studies using patient-reported outcome measures suggest telerehabilitation can lead to improved outcomes relating to self-reported daily functioning and quality-of-life [(33, 34, 36, 37)]. In addition, there is generally a high level of acceptability from patients for this shift in service delivery [(31, 32, 33)]. However, there remain certain distinct challenges associated with telerehabilitation which may curtail the extent to which this approach is adopted and retained more widely.

Measuring benefits and acceptability of interventions

One difficulty associated with comparing results across studies is the lack of consensus when measuring outcomes. Across all ten studies identified in this review, 27 different outcome measures were used to assess the benefits of telerehabilitation. These included both performance-based assessments, such as psychometric testing, and subjective or patient-reported measures of health status, visual functioning and quality of life. In the four studies which used patient-reported outcomes, just one measure (SF-36) was used in more than one study. An important consideration for clinicians, researchers and trialists could be to aim for a more unified approach when deciding on a core set of outcome measures in future trials and evaluations of telerehabilitation. Secondly, whilst it is encouraging that patients' views and experiences are being considered when measuring the benefits of telerehabilitation, it is important to consider the sensitivity of outcome measures to meaningful changes in areas such as functionality, symptomatology, and quality-of-life etc. For example, the non-significant changes in quality-of-life observed in the study by Sabel and Gudlin [34] could be explained by the use of non-disease-specific measures, which may not be sufficiently sensitive to detect small or subtle changes in visual function [54]. Finally, the evidence synthesised in this review suggests that telerehabilitation is generally regarded as acceptable by those who are willing to engage with it. Yet, acceptability is a multifaceted concept which may not be fully explained by quantitative behaviour metrics such as the degree of adherence or engagement with an intervention. No studies included in this review describe a framework for acceptability, indicating further research is needed to understand acceptability of telerehabilitation using a robust assessment of relevant factors such as affective attitudes, opportunity costs, ethicality, and self-efficacy; thus, future studies investigating acceptability may benefit from a theoretical framework to guide the assessment of acceptability [55].

Recommendations and challenges in practise

Several of the studies in this review included recommendations for telerehabilitation which provide helpful insights. For example, a period of direct training with home-based technology was regarded positively, suggesting such training can provide patients with a helpful rehabilitation framework. Despite an increasing number of visually impaired adults engaging with technology [56], it is inevitable that some individuals will have underlying concerns about their technical readiness to operate devices at home. An assessment of individual self-efficacy regarding health management and aptitude for telerehabilitation may, therefore, help to prioritise individuals for whom this approach is most likely to be acceptable and successful.

A key challenge associated with telerehabilitation is maintaining patient motivation and engagement. Rehabilitation is, by nature, highly repetitive and often requires engagement over long periods of time before measurable improvements in areas such as functional vision can be observed. Although studies in this review yielded good patient satisfaction ratings [33] and high retention rates [32], it is difficult to predict the sustainability of telerehabilitation outside the context of a research study. For example, devices risk becoming a nuisance if required long term, and whilst acceptable within research, patients may resist such commitments becoming the standard of care. Similar findings regarding the acceptability of telerehabilitation have been described in a recent systematic review of telerehabilitation for improving adaptive skills in people with multiple disabilities [57], which found that patients are particularly satisfied with the convenience of undergoing rehabilitation from home. However, studies in this review described potentially intensive programmes of telerehabilitation, in some instances requiring several hours of engagement on consecutive days per week. For example, Tinelli and colleagues' [35] participants were asked to use the telerehabilitation tools for 5-days per week for up to 12-months. Further research using real-world data on patterns of engagement with telerehabilitation will be a valuable addition to the literature and could help to identify factors associated with adherence and withdrawal, and behavioural strategies to encourage adoption.

Cost and capacity considerations

One aspect of telerehabilitation which increases its appeal is the potential for substantial direct and indirect cost savings. The 2019 study by Ihrig [39] highlighted that telerehabilitation was associated with considerable time and cost savings for patients by reducing travel requirements and fuel consumption. However, in cases where individual specialist equipment was required, such as the adapted telephone system in the study from Lancioni and colleagues [37], costs per unit were expected to be in the region of $2,000 USD. The economic value of telerehabilitation from a provider perspective requires more research. For example, additional costs may be incurred for services such as training, measurement readings, data management, and ongoing maintenance of many devices. Indeed, remote service delivery has been associated with slightly higher costs to service providers, such as speech therapy in people with Parkinson's disease [58]. Nevertheless, it could be expected that remote rehabilitation costs would be largely absorbed by the reduced need for time and resources required for non-remote services. It is noteworthy that telerehabilitation may have a wider reach than standard rehabilitation services, and the increased availability and convenience of a remote service may be more appealing to a broader profile of patients (e.g., working age individuals with minimal time for in-person sessions). As shown by Ihrig [39], remote service delivery led to an average workload increase of 24% due to a higher number of patients accessing the service. If this finding applied to a broader audience, there will likely be a larger rehabilitation patient caseload, with possible capacity implications for clinical practice.

Limitations of identified studies

Although no studies were formally excluded on the basis of insufficient quality (inclusion threshold set at 55% [0.55]), some common study limitations were identified. The most frequent issues with the studies according to the Kmet et al checklist was the presence of only a partial description of subject characteristics (2 of 10) and study conclusions not being fully supported by the data (3 of 10). Additionally, the majority of the studies introduce a self-selection bias when participants elect to take part in research and are willing to engage with telerehabilitation programmes. Although common in cross-sectional research, self-selection bias can complicate the interpretation of study data as participants' propensity for participating in research may correlate with the topic under investigation. For example, Lorenzini and Wittich [32] report that 79% of eligible participants declined to take part in the study. As such, the conclusions are based on a relatively small proportion of the target population. Reasons for non-participation were seldom discussed in the published reports; therefore, it is unclear whether factors such as level of familiarity with devices, visual functioning, extent of sight impairment, or having assistance from a sighted friend or family member impact on engagement with telerehabilitation. In addition, the studies in this review report the outcomes of telerehabilitation after a relatively short period of time (i.e., less than 1-year). As observed by Lorenzini and Wittich [32], engagement is more likely to decrease after 6 months, highlighting the need for more longitudinal studies. A further common limitation was the relatively small sample sizes observed in the studies. For example, four of the ten studies included in this review had a sample size of 10 or fewer. Although this review set out to describe the type of telerehabilitation for people with vision impairment, participants across the identified studies were mostly low vision patients with mild or moderate visual loss; therefore, the findings may not extend to other subgroups within the vision impairment population, such as those with severe sight impairment or no perception of light. There are currently very few randomised controlled clinical trials evaluating patient outcomes in telerehabilitation, for example, three of the ten studies identified in this review used random allocation to an intervention and control group [32, 33, 34], and we propose this would be an important avenue for further research, as well as comparisons between traditional face-to-face and telerehabilitation services to understand the challenges associated with telerehabilitation in the specific context of vision impairment.

Limitations

This review's methodology has a number of limitations. Only articles written in English were screened and ultimately included, thus excluding potentially relevant studies in languages other than English. However, only three studies were excluded for this reason. Moreover, included studies were required to relate to some form of vision impairment, and several studies included heterogenous samples of varying or unknown degrees of sight loss from numerous conditions. A range of vision impairment terms were used across the studies including 'sight loss', 'blindness' and 'low vision'. Results were rarely disaggregated by disease severity or type, thereby making it difficult to account for potential nuances between different patient groups under the broad overarching term of 'vision impairment'. A key strength of this review was the inclusion of grey literature. Grey literature includes a range of documents not controlled by commercial publishing organisations and can be a rich source of information which cannot be obtained from other sources [59]. This review highlights that the availability of telerehabilitation through local charity networks appeared to vary depending on location. While a paucity of online documentation regarding charity telerehabilitation services in some regions does not necessarily equate to an absence of such services, it does suggest a possible unevenness in their availability across local authorities. This may reflect broader issues pertaining to unequal access to sight loss support nationwide. As telerehabilitation continues to emerge as an effective and potentially permanent fixture in the care pathways of visually impaired people, there is a need to bridge the gaps in service delivery to ensure there is equitable provision across all areas of the UK, particularly given the potential for a wider geographical reach with remote services thereby increasing access to support.

Conclusions

In summary, the COVID-19 pandemic necessitated a redesign of traditional face-to-face rehabilitation pathways to remote service delivery. A previous systematic review assessing the effectiveness of low vision telerehabilitation found no studies had been completed in this area [23]. We identified a range of remote-based rehabilitation services aimed at optimising vision and encouraging adjustment to sight loss, with evidence to suggest some patients are generally accepting of this model and may benefit from improved functional and quality-of-life outcomes, whilst potentially offering a more cost-effective approach to continuing care. The weight of the evidence suggests telerehabilitation has a promising role in patient care pathways for people with a vision impairment; however, issues around long-term desirability and compliance remain unclear. Given the variability in patients' aptitude and motivation to sustainably engage with telerehabilitation, a self-select approach which allows patients to choose their preferred mode of rehabilitation delivery or individualised interventions may be the most practical means of ensuring effective implementation of remote services. This review has addressed increasingly relevant questions about the role of telerehabilitation when applied among visually impaired people. The findings to date illustrate the benefits of remote rehabilitation services, but more research is needed to better understand its overall effectiveness, scalability and longevity. Ultimately, we hope this review can inform key stakeholders, including hospital eye services, community groups, and charities about priority areas for future research and development.

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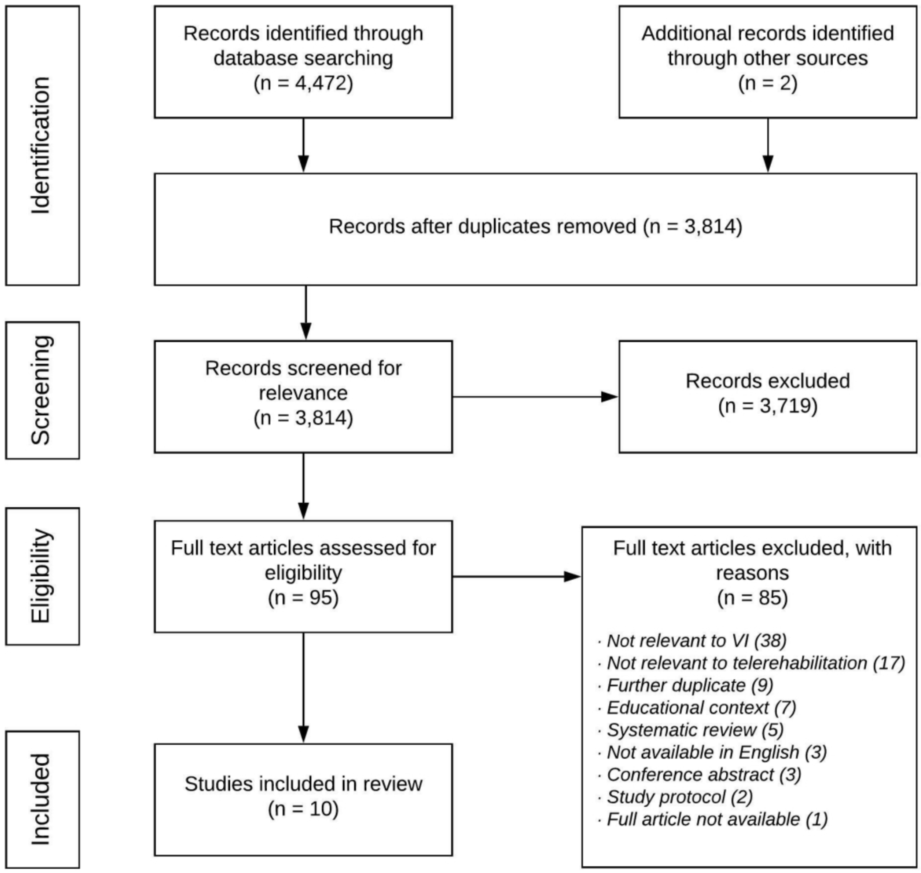

Figure 1. PRISMA diagram showing study selection process. Key: VI = vision impairment

170x159mm (300 x 300 DPI)

Supplementary material 1 – Quality appraisal

Quantitative studies (N=9)

Authors	Is the question / objective sufficiently described?	Is the study design evident and appropriate?	Is the method of subject/comparison group selection or source of information/input variables described and appropriate?	Are the Subject (and comparison group, if applicable) characteristics sufficiently described?	If interventional and random allocation was possible, was it described?	If interventional and blinding of investigators was possible, was it reported?	If interventional and blinding of subjects was possible, was it reported?	Are outcome and (if applicable) exposure measure(s) well defined and robust to measurement / misclassification bias? Are means of assessment reported?	Is the sample size appropriate?	Are the analytic methods described/justified and appropriate?	Is some estimate of variance is reported for the main results?	Controlled for confounding?	Are results reported in sufficient detail?	Are conclusions supported by the results?	Overall score
Bittner *et al.*, 2018	Yes (2)	Yes (2)	Yes (2)	Yes (2)	N/A	N/A	N/A	Yes (2)	N/A	Yes (2)	Yes (2)	N/A	Yes (2)	Yes (2)	1.00
Dogru-Huzmeli *et al.*, 2021	Yes (2)	Yes (2)	N/A	Partial (1)	N/A	N/A	N/A	Partial (1)	N/A	N/A	N/A	N/A	Partial (1)	Partial (1)	0.67
Ihrig, 2019	Yes (2)	Yes (2)	N/A	Partial (1)	N/A	N/A	N/A	Yes (2)	N/A	Yes (2)	Yes (2)	N/A	Yes (2)	Yes (2)	0.94
Lancioni *et al.*, 2011	Yes (2)	Yes (2)	N/A	Yes (2)	N/A	N/A	N/A	Partial (1)	N/A	N/A	No (0)	N/A	Yes (2)	Yes (2)	0.64
Lorenzini & Wittich, 2021	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	N/A	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	1.00

Lorenzini & Wittich, 2021	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	N/A	Yes (2)	Yes (2)	Yes (2)	N/A	Yes (2)	Yes (2)	Yes (2)	1.00
Sabel & Gudlin, 2014	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Partial (1)	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Partial (1)	0.93
Senjam *et al.*, 2021	Yes (2)	Yes (2)	Yes (2)	Yes (2)	N/A	N/A	N/A	Yes (2)	N/A	N/A	N/A	N/A	Yes (2)	Partial (1)	0.93
Tinelli *et al.*, 2017	Yes (2)	Yes (2)	Partial (1)	Yes (2)	N/A	N/A	N/A	Yes (2)	N/A	Yes (2)	Yes (2)	N/A	Yes (2)	Yes (2)	0.94

Qualitative study (N=1)

Authors	Question / objective sufficiently described?	Study design evident and appropriate?	Context for the study clear?	Connection to a theoretical framework / wider body of knowledge?	Sampling strategy described, relevant and justified?	Data collection methods clearly described and systematic?	Data analysis clearly described and systematic?	Use of verification procedure(s) to establish credibility?	Conclusions supported by the results?	Reflexivity of the account?	Overall score
Dunne *et al.*, 2020	Yes (2)	Yes (2)	Yes (2)	Yes (2)	Partial (1)	Yes (2)	Partial (1)	Yes (2)	Yes (2)	Partial (1)	0.85

Supplementary material 2 – Data extraction table

Authors	Study title	Design	Domain(s) of outcomes	Location	Study objectives	Study populations	Main results/conclusions
Bittner *et al.*, 2018	Feasibility of telerehabilitation for low vision: satisfaction ratings by providers and patients	Experimental	Patient satisfaction and recommendations	USA	To develop, administer, refine and evaluate components required to deliver follow-up low vision telerehabilitation services.	10 participants with self-rated vision ranging from good to poor. 9 with AMD; 1 with DR. Average age 80 (range = 63-91) years.	Providers and participants rated video quality as excellent to good. Audio quality ratings were variable, generally related to signal strength or technical issues during some sessions. All participants agreed that they were satisfied and comfortable receiving telerehabilitation. Eight of 10 reported that their magnifier use improved. All except one reported that they were very interested in receiving telerehabilitation again. Positive feedback from both participants and providers in this pilot study supports the feasibility, acceptability, and potential value of low vision telerehabilitation.
Dogru-Huzmeli *et al.*, 2021	Can diplopia complaint be reduced by telerehabilitation in multiple sclerosis patient during the pandemic? A case report	Case report	QoL and well-being	Turkey	To determine the effect of Cawthorne-Cooksey exercises applied via telerehabilitation on eye movements, vision, and quality of life in a multiple sclerosis patient with diplopia.	1 male participant with multiple sclerosis aged 39 years.	Following 4 months of telerehabilitation, the participant stated that his double vision complaints decreased, and his eyes could move more easily. When eye movements were evaluated, outward gaze restriction had improved. There was no change in visual acuity, anterior and posterior segment examinations, and OCT examination. It can be feasible to administer Cawthorne-Cooksey exercises using telerehabilitation to reduce diplopia.
Dunne *et al.*, 2020	Maximizing telerehabilitation for patients with visual loss after stroke: interview and focus group study with stroke survivors, carers, and	Qualitative	Patient satisfaction and recommendations	UK	To identify barriers and facilitators using rehabilitation tools and elements of good practice in telerehabilitation among stroke survivors.	66 focus group participants. 32 stroke survivors with partial vision loss (18 men; aged 43-83 years, mean age 62.28 years), 10 carers (7 women; 41-75 years, mean age 54.70 years), and 24	Themes identified problems associated with poststroke health care from both patients' and occupational therapists' perspectives that need to be addressed to improve uptake of telerehabilitation. Themes included identifying additional materials or assistance to boost the impact of training packages. Perceptions of technology were considered a barrier

Authors	Study title	Design	Domain(s) of outcomes	Location	Study objectives	Study populations	Main results/conclusions
	occupational therapists					occupational therapists (19 women; 22-45 years, mean age 31.13 years)	by some but a facilitator by others. In addition, 4 key features of telerehabilitation were identified: additional materials, the importance of goal setting, repetition, and feedback.
Ihrig, 2019	Travel cost savings and practicality for low vision telerehabilitation	Cost analysis	Cost-effectiveness	USA	To evaluate patient acceptance and practicality of low vision telerehabilitation.	419 veterans, average age 83 (range = 50-101) years. 406 were male. 208 had diagnosis that resulted in non-correctable or best corrected visual acuity in both eyes up to 20/150 (defined as not legally blind); 149 had non-correctable or best corrected visual acuity in both eyes of 20/200 or worse (defined as legal blindness); 22 had non-correctable peripheral visual field loss in one or both eyes >20 degrees (defined as not legally blind); and 40 had non-correctable peripheral visual field loss in both eyes <20 degrees (defined as legal blindness).	Of the 419 veterans seen since November 2012 (FY 13), the median saving of travel miles for rural patients was 122 miles per veteran (51,136 miles/419 veterans) and the median saving of travel time was 2.09 h per veteran (878 h/419 veterans). Overall, the median saving of the travel cost per rural individual (utilizing $0.535 per mile) was $65.29 per veteran ($27,357.76/419). Travel mileage and time saving resulted in an increase in access to low-vision rehabilitation (24% increase in partially sighted veterans evaluated in 5 years) by reducing the veteran's travel distance, time, and cost. Utilising low vision telerehabilitation increases early access and enables veterans who cannot travel to a specialty clinic the opportunity to prevent potential decline in functional ability over time.
Lancioni *et al.*, 2011	Enabling two women with blindness and additional disabilities to make phone calls independently via a	Case report	QoL and well-being	Italy	To assess whether two women with blindness and additional disabilities could make independent phone calls through a	Two female participants aged 30 and 41 years. One participant with retinopathy and congenital cataract leading to total blindness by age 28.	Both participants learnt to use the system and made phone calls independently to family members, friends and staff personnel. Neither participant made calls independently at baseline. During the first intervention phase, one participant had a mean cumulative conversation time per

Authors	Study title	Design	Domain(s) of outcomes	Location	Study objectives	Study populations	Main results/conclusions
	computer-aided telephone system				computer-aided telephone system.	One congenitally blind participant due to gestational complications.	session of ~11 minutes. The mean length of the sessions was ~21 minutes. For the second participant, mean (cumulative) conversation time per session was ~10 minutes. The mean length of the sessions was ~17 minutes.
Lorenzini & Wittich, 2021	Personalised telerehabilitation for a head-mounted low vision aid: A randomized feasibility study	Randomised controlled trial	Patient satisfaction and recommendations	Canada	To determine the feasibility of telerehabilitation using eSight eyewear with low vision participants. Feasibility defined as achieving recruitment target, proportion of participants lost to follow up, and whether the intervention was accessible and acceptable.	57 participants; 58% male, average age 54.5 (range = 21-82) years. All were categorised as having an ocular disease, most common were optic nerve disease, AMD, RP, and retinopathy of prematurity.	Withdrawal rate was higher in the control group but did not differ significantly from the experimental group. High accessibility (93% of participants accessed the platform) and global acceptability (100% overall satisfaction) were reported among those who completed the telerehabilitation protocol. The therapist had no difficulty judging the participants' reading performances qualitatively while participants used their device to read their eSkills and VisExc guides. Most participants improved their daily activities, based on qualitative reports of the attained goals. Seventy-nine percent of individuals declined to participate, whereas 16% of participants decided not to use eSight Eyewear anymore. Positive feedback from the participants and the low vision therapist suggests the potential value of this modality for low vision services.
Lorenzini & Wittich, 2021	Head-mounted visual assistive technology–related quality of life changes after telerehabilitation	Randomised controlled trial	Patient satisfaction and recommendations / QoL and well-being	Canada	To explore the effect of telerehabilitation (eSight eyewear) on quality-of-life and functional vision in individuals with low vision using a head-mounted display.	57 participants; 58% male, average age 54.5 (range = 21-82) years. All were categorised as having an ocular disease, most common were optic nerve disease, AMD, RP, and retinopathy of prematurity.	Assistive technology–related quality of life was improved when measured by the satisfaction scale but not the psychosocial scale within the first 3 months, independently of training type. Overall, functional vision improvement was observed within the first 2 weeks of device use and maintained during the 6-month study, independently of group type. eSight Eyewear, either with telerehabilitation or with the manufacturer

Authors	Study title	Design	Domain(s) of outcomes	Location	Study objectives	Study populations	Main results/conclusions
							self-training comparison, improved functional vision and increased users' quality of life within the initial 3 months of device training and practice.
Sabel & Gudlin, 2014	Vision restoration training for glaucoma: A randomized clinical trial	Randomised controlled trial	Vision training / QoL and well-being	Germany	To determine if behavioural activation of areas of residual vision using daily 1-hour vision restoration training for glaucoma for 3-months improves detection accuracy compared with placebo.	30 participants; 14 male; mean [SD] age 61.7 [10.1] years; 20 participants with primary open angle glaucoma; 5 with normal tension glaucoma; 4 with secondary glaucoma; 1 with angle-closure glaucoma. Mean [SD] visual acuity was 0.62 [0.34] (range 0.0-1.3 logMAR) in the right eye and 0.76 [0.40] (range 0.0-1.8 logMAR) in the left eye.	Vision restoration training for glaucoma led to significant detection accuracy gains in high-resolution perimetry (P = .007), which were not found with white-on-white or blue-on-yellow perimetry. Pre-post differences after vision restoration training for glaucoma were greater compared with placebo in all perimetry tests (P = .02 for high-resolution perimetry, P = .04 for white on white, and P = .04 for blue on yellow), and these results were independent of eye movements. Vision restoration training for glaucoma (but not placebo) also led to faster reaction time (P = .009). Vision-related quality of life was unaffected, but the health-related quality-of-life mental health domain increased in both groups.
Senjam *et al.*, 2021	Tele-rehabilitation for visually challenged students during COVID-19 pandemic: Lesson learned	Case report	Managing symptoms	India	To report experiences of a telerehabilitation service available primarily for students with visual disabilities amidst the COVID-19 pandemic.	492 participants; male = 388. The majority of beneficiaries were between 11 and 30 years (82.3%). Around 96% of beneficiaries were visually disabled, and 16.5% had unknown visual status (waiting or applied for certificates).	The most common ocular complaints for which beneficiaries required advice were itching (N= 121; 36.1%); watering eyes (N = 54; 16.1%); painful eyes (N = 12; 3.6%), redness (N = 5; 1.5%). Telerehabilitation can offer a safe and efficient means of providing reliable information to visually impaired individuals.

Authors	Study title	Design	Domain(s) of outcomes	Location	Study objectives	Study populations	Main results/conclusions
Tinelli *et al.*, 2017	Development and implementation of a new telerehabilitation system for audio-visual stimulation training in hemianopia	Experimental	Vision training	Italy	To test the feasibility and efficacy of audio-visual telerehabilitation in three adult patients with chronic visual field defects.	Three participants with hemianopia. One male had cerebral stroke; one adult had drug-resistant epilepsy caused by a focal cortical dysplasia type 2a; one male had partial left homonymous hemianopia following surgery for a meningioma in the right hemisphere.	Results suggest audio-visual telerehabilitation is an effective treatment based on the stimulation of ocular movements and visual exploration functions through compensative strategies. Patients were instructed to use saccadic eye movements for the detection of visual targets and thus they showed, at the end of the treatment, an activation of the oculomotor system and a change in responsiveness toward visual stimuli, confirmed by behavioural data, mostly using the Unimodal Visual Test. The test allows patients to exercise independently in a familiar context, while under remote supervision. It may give the patient a sense of control and autonomy, which can contribute to a better therapy outcome, also reducing the need for one-to-one treatment time and home visits.

Supplementary material – Data extraction table. Data extraction table. **Key** - QoL: quality-of-life. AMD: age-related macular degeneration. DR: diabetic retinopathy. RP: retinitis pigmentosa. SD: standard deviation. logMAR: logarithm of the minimum angle of resolution. OCT: optical coherence tomography. FY: fiscal year.

Supplementary Material 3 – Charities delivering remote rehabilitation

Organisation	Remote services
Beacon Centre for the Blind	Telephone-based welfare calls and befriending service. Life skills sessions to promote independent living.
Blind Veterans UK	Practical skills training including maintaining personal (e.g., managing medications) and domestic (e.g., preparing meals) activities of daily living. Remote befriending service and communication technology skills training.
Essex Sight	Telephone-based welfare calls, demonstration of equipment (e.g., kitchen aids and lighting).
Henshaws	Telephone-based welfare calls, befriending groups, physical exercise training (e.g., improving movement, strength and fitness), digital enablement services.
Galloway's	Digital skills training
My Sight Nottinghamshire	Telephone-based befriending, digital skills training, physical exercise training (e.g., chair-based and standing exercises).
Peterborough Association for the Blind	N/A
Sight for Surrey	Digital skills training, assistive technology training (e.g., screen magnification software), communication skills training, everyday living skills advice.
The Cambridgeshire Society for the Blind and Partially Sighted	Telephone-based welfare calls, peer support groups, digital skills training.
Vista	Digital skills training, assistive technology training (activating and optimising accessibility features), life skills (e.g., meal preparation), online well-being activities (e.g., singing and gardening)
The Royal National Institute for Blind People	Telephone-based counselling and befriending groups, signposting to online resources, online activities

Supplementary material – Charities delivery remote rehabilitation. **Key** - N/A: not available

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	5-6
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	6, 8
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	9
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	7-8
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	7-8
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	7
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	8
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	8 + Supplementary material
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	8 + Supplementary material
Critical appraisal of individual	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe	8-9

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
sources of evidence§		the methods used and how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	8-9
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	10
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	10 + Supplementary material
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	10 + Supplementary material
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Supplementary material
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Supplementary material
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	10-19
Limitations	20	Discuss the limitations of the scoping review process.	23
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	24
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	24

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

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