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ORIGINAL RESEARCH

The Basic VRS-Effect Study: Clinical Trial Outcomes and Cost-Effectiveness of Low Vision Rehabilitation in Portugal

Laura Hernández-Moreno · Hugo Senra · Ana Patricia Marques · Natacha Moreno Perdomo · Antonio Filipe Macedo

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ABSTRACT

Introduction: The aim of this study was two-fold: (1) to investigate the clinical impact of vision rehabilitation in patients with vision impairment and (2) to investigate the cost-effectiveness of a basic vision rehabilitation service in Portugal.

Methods: The trial recruited patients diagnosed with age-related macular degeneration or diabetic retinopathy (DR) and visual acuity in the range 0.4–1.0logMAR in the better-seeing eye. Participants were randomised to one of the study arms consisting of immediate intervention and delayed intervention. The intervention included: new refractive correction, optical reading aids, in-office training and advice about modifications at home. Visual ability, health-related quality of life and costs were measured. Economic analysis was performed to evaluate whether the intervention was cost-effective. The trial compared the outcomes 12 weeks after the start in both arms.

Results: Of the 46 participants, 34 (74%) were diagnosed with DR, 25 (54%) were female, and mean age was 70.08 years (SD = 8.74). In the immediate intervention arm visual ability increased a mean of 0.523 logits (SE = 0.11) ($p < 0.001$). Changes in the delayed intervention arm were not statistically significant ($p = 0.95$). Acuity in the better-seeing eye, near acuity and critical print size also improved during the study. The mean cost of the intervention was €118.79 (SD = 24.37). The incremental cost-effectiveness ratio using the EQ-5D-

L. Hernández-Moreno · A. F. Macedo (✉)
Department and Center of Physics-Optometry and Vision Science, University of Minho, Braga, Portugal
e-mail: a.macedo@ulc.ac.uk; antonio.macedo@lnu.se

H. Senra
Centre for Research in Neuropsychology and Cognitive and Behavioural Intervention (CINEICC), University of Coimbra, Coimbra, Portugal

H. Senra
School of Health and Social Care, University of Essex, Colchester, UK

A. P. Marques
International Centre for Eye Health, London School of Hygiene and Tropical Medicine, London, UK

A. P. Marques
Comprehensive Health Research Centre, National School of Public Health Nova University of Lisbon, Lisbon, Portugal

N. M. Perdomo
Hospital Santa Maria Maior E.P.E., Barcelos, Portugal

A. F. Macedo
Department of Medicine and Optometry, Linnaeus University, Norra Kajplan 6, Hus Vita, 39182 Kalmar, Sweden

5L was 30,421€/QALY and 1186€/QALY when using near acuity.
Conclusion: The current study gives evidence of positive clinical impact of a basic vision rehabilitation intervention and shows that a basic vision rehabilitation service is cost-effective. These findings are important to clinical and rehabilitation practices and for planning vision rehabilitation services.
Trial Registration: Retrospectively registered, 21/01/2019. ISRCTN10894889, https://www.isrctn.com/ISRCTN10894889

PLAIN LANGUAGE SUMMARY

There is limited research addressing the actual impact of vision rehabilitation. The current trial compares the effect of a basic vision rehabilitation intervention with usual care on patients' functioning. The intervention was clinically impactful and cost-effective.

Keywords: Randomised controlled trial; Vision impairment; Low vision; Vision rehabilitation; Visual ability; Magnification; Health-related quality of life; Cost-effectiveness

Key Summary Points

People with sight loss can have vision impairment that leads to disabilities and handicaps.

There is currently a lack of evidence about the cost-effectiveness of basic low vision rehabilitation to tackle low vision-related disabilities.

The current study confirmed that a basic low vision rehabilitation intervention reduces disabilities and improves quality of life in people with impaired vision. Findings revealed that such interventions are cost-effective.

The current study provides the evidence needed to include low vision rehabilitation as part of the clinical referral pathway where services exist.

The study raises the need to further research and develop vision rehabilitation services and education for optometrists, ophthalmologists and related professionals.

INTRODUCTION

Globally, millions of people live with some level of vision impairment (VI) [1–3]. VI is a common cause of disability affecting patients' well-being, mental health, activities of daily living and social functioning (e.g. independence or difficulties in finding a job) [4–10]. VI leads to significant economic burdens due to direct costs (inpatient and outpatient care) and indirect costs (informal care or productivity losses) [7, 8, 11–14]. For example, reduced independence to perform activities of daily living can lead to fewer job opportunities due to reduced ability to work [15–17]. Vision rehabilitation can be effective in tackling these limitations and promoting independent living and autonomy in people with VI [18].

Vision rehabilitation (VR) can be defined as a mixture of health, educational and social interventions whose ultimate goal is to reduce the negative impact of VI. The aim of these services is to improve visual ability (the ability to perform tasks that rely on vision) [19, 20] and other aspects associated with VI such as the psychosocial burden [18, 21]. VR works by enhancing visual function, which includes, for example, the use of assistive devices or changes in the visual environment such as improved lighting. VR often requires the acquisition of new skills such as handling assistive devices or accessibility features in ordinary electronic devices [22, 23]. With rehabilitation, activities that rely on vision are expected to become

easier to perform even without improvement in visual acuity [6, 21, 24, 25].

The Portuguese visual impairment study group (PORVIS group) [26] has carried out some studies showing that VI is common in Portugal and that many people are still struggling to cope with the condition [7–9, 26–29]. The prevalence of age-related macular degeneration (AMD) in Portugal is close to 13% [30] and the prevalence of diabetic retinopathy (DR) amongst people diagnosed with diabetes is close to 16% [31]. A recent study has revealed that DR and AMD are the two most common causes of irreversible VI in Portugal [29]. In general, there is a lack of studies examining the benefits of VR for people with VI, which hinders the development of vision rehabilitation systems (VRS) [32–35]. Magnifiers, for example, have been regularly dispensed in many hospitals since at least 1970 [36]. However, a systematic review showed that better evidence on the benefits of using magnifiers is necessary [37]. In short, more research addressing the actual impact of VR on patients' functioning is needed to inform clinicians and rehabilitation professionals on the best practice for visually impaired patients.

The aim of this trial was twofold: (1) to assess the effect of a basic vision rehabilitation intervention on visual ability in people with impaired vision and (2) to report the cost-effectiveness of a basic vision rehabilitation service provided in a Portuguese setting.

METHODS

This study was part of a clinical trial addressing the cost-effectiveness of a basic vision rehabilitation service in Portugal (registration number: ISRCTN10894889). The study was approved by the Ethics Committee for Life Sciences and Health of the University of Minho (SECVS 147/2016) and the Hospital Santa Maria Maior's ethics committee, Portuguese data protection authority approval number: 7012/2017. Patients gave written informed consent for participation in this study. The study conformed to the tenets of the Declaration of Helsinki.

Patients attending outpatient appointments at the department of ophthalmology at a public hospital in Portugal were invited to participate in this study. The inclusion criteria were: (1) visual acuity between 0.4 and 1.0 logMAR in the better-seeing eye; (2) primary diagnosis and main cause of vision loss should be diabetic retinopathy or age-related macular degeneration; (3) 18 years or older; (4) living in the community (not living in any type of institution). The exclusion criteria were: (1) cognitive impairment based on scores on mini-mental state examination; (2) communication problems due to, for example, hearing impairment or inability to speak Portuguese; (3) inability to read because of a low level of education; (4) inability to attend the requested appointments at the study setting.

The study design was a parallel group, 1:1 allocation ratio randomised controlled trial. Participants were allocated to an immediate intervention arm (IMI) or a delayed intervention arm (DEI). The IMI arm received the intervention at the first visit (baseline); the DEI arm was used as control for a possible effect of 'attention to the problem' and participants were put on a waiting list—participants in this arm only received the intervention in the second visit—12 weeks after the start of the study.

The basic vision rehabilitation intervention (VRI) consisted of three main components: (1) prescription, when necessary, of the best refractive correction for distance vision; (2) prescription of magnification for reading (near glasses or handheld magnifiers); (3) instructions and training. The detailed procedure for each step of the intervention has been published as part of the study protocol [38]. The intervention was defined by the research team and based on the local circumstances and their knowledge about the needs of visually impaired people in Portugal. The intervention was also in line with the recommendations of the WHO Package of Eye Care Interventions-Annex 6 released in 2022 [39].

Main Outcome Measure and Vision Measures

Main Outcome

Visual ability was measured with the Portuguese version of Massof Activity Inventory (AI) [7, 8, 40, 41]. The AI consists of a hierarchal structure in which specific cognitive and motor visual tasks (e.g., pouring or mixing without spilling) underlie more global goals (e.g., preparing meals) [42, 43]. Disabilities occur when an individual reports difficulty in achieving important goals. Goals are split among three objectives—social functioning, recreation and daily living—associated with four classes of function: reading, visual motor (also called manipulation), visual information (also called seeing) and mobility [42, 43]. Goals rated "not important" are skipped and as such are not considered in the final visual ability score as these are not relevant to the person's daily life. For goals rated "slightly important" or beyond, participants are asked to rate difficulty on a five-point scale ranging from "not difficult" to "impossible to do" [42, 43].

Vision Outcomes

Distance visual acuity (VA) was measured with Early Treatment Diabetic Retinopathy Study (ETDRS) charts in a dimly lit room using an internally illuminated cabinet (model 2425E). Near VA was assessed with near version of the ETDRS charts (https://www.precision-vision.com/). VA was measured monocularly at distance and binocularly at near. At both distances a letter-by-letter scoring was used [41, 44]. Testing distance was adjusted according to the severity of vision loss; final acuity scores reported were adjusted to standard distances (4 m at distance and 40 cm at near).

Reading was tested to determine vision-related reading difficulties. Specifically, we measured: (1) reading acuity (RA), (2) maximum reading speed (MRS) and (3) critical print size (CPS) using the Portuguese version of Minnesota low vision Reading Test (MNread test) [45–47]. Reading was measured binocularly at 40 cm or 20 cm according to the needs. After the intervention, reading was assessed with the prescribed aid.

Contrast sensitivity was assessed binocularly at 40 cm with near correction using the MARS test (https://www.marsperceptrix.com/), which has a gradual letter-by-letter contrast. In line with the test settings, illuminance on the surface of the test was approximately 330 lux. Participants were encouraged to respond until two consecutive letters were read incorrectly; scoring was performed according to the test instructions.

Economic Evaluation

Measures of Costs

Rehabilitation costs included: hospital costs, distance glasses (when necessary), near glasses and handheld magnifiers. The hospital costs included overheads for facilities and equipment and optometrist's time. Costs for optical devices prescribed were inputed using the price recommended for the public [38]. Costs were estimated using the health care system perspective. We estimated a cost of €4.84 for each appointment for the material and equipment (e.g., visual tests and visual aids trial set) needed to provide a basic rehabilitation in a hospital. The time spent by the rehabilitation optometrist with each patient was 1 h 45 min at 8.35 €/hour (15 min preparation, 1 h examination and 30 min dispensing and training). Overhead hospital costs included administrative and clerical support and were estimated using hospital annual reporting costs for the ophthalmology department (€11.81 per patient). Magnifiers and/or lenses for glasses were also included in the cost's estimation.

Measures of Effectiveness

Health-related quality of life (HRQOL) was accessed with the EuroQol five-dimension, 5-point response scale questionnaire (EQ-5D-5L). This questionnaire comprises five dimensions which have five possible levels of response. Three dimensions are related to function (Mobility, Self-Care and Usual Activities) and the other two describe feelings (Pain/Discomfort and Anxiety/Depression) [48, 49].

Utility index values were obtained using "index value set calculators" obtained from https://euroqol.org/ that use valuations of health states in England. We used values from England because some of the health states in our sample were unavailable in the standard EQ-5D-5L value set for Portugal [50].

Near VA values were converted to quality-adjusted life years (QALYs), as suggested by others [51, 52]. The reference for near vision ophthalmic utility value was the value of time trade-off utility values for patients with ocular diseases [53].

Economic and Sensitivity Analysis

Economic analysis was conducted from the healthcare perspective. All costs are reported in euros for year 2020. EQ-5D-5L index and near vision were measured before the intervention and 12 weeks after to capture the effect of the intervention. To determine whether the intervention was cost-effective the incremental cost-effectiveness ratio (ICER) was computed using the expression:

$$\text{ICER} = (\text{Cost intervention} - \text{Cost alternative})/(\text{Effect intervention} - \text{Effect alternative})$$

From the IMI arm we obtained the "cost intervention", which is the rehabilitation costs and the "effect intervention", which is the utility values from EQ-5D-5L and from the near vision ophthalmic utility value at 12 weeks. From the DEI arm we obtained the "cost alternative", which was zero (because the group was in a waiting list) and the "effect alternative" or "placebo".

To assess whether the intervention was cost-effective, the threshold used was based on the Portuguese per capita Gross Domestic Product (GDP) of €19,431 for 2020 [54]. To determine confidence intervals we used a procedure implemented in previous studies [55, 56]. In short, we used bootstrapping with 5000 replications for the costs and for the effects in both groups to generate 95% confidence intervals around the ICER estimates. Cost-effectiveness planes were plotted to show the distribution of costs and effects. Cost-effectiveness acceptability curves to show the probability of cost-effectiveness at a range of thresholds were also plotted. Adjusted intervention cost sensitivity analyses were performed to evaluate uncertainty. For that, we computed the ICER for empirical costs values and then computed ICER for extreme cost values.

Statistical Analysis

Descriptive statistics and hypothesis testing were performed according to the type of variable (continuous or discrete) and its distribution (normal or skewed). Kolmogorov-Smirnov test was performed to assess normality. Rasch analysis was carried out to analyse results of the AI using the Andrich rate scale model [57] for polytomous data with Winsteps software (v. 4.4.0) to compute person measures of visual ability [58]. The effect of time and group on trial outcomes was tested using linear mixed models (LMM) using PROCMIX in SAS software (R: 3.8, SAS Institute Inc., Cary, NC, USA). For the main outcome measure, visual ability was normalized by subtracting the AI person measure at week 1 from all measures, corresponding to a baseline visual ability of 0 for all participants. For this model visual ability was defined as "dependent variable"; participants were defined as "random factors" or "group specific effects". Explanatory factors or "fixed factors" were: "arm" and time (1, 12 and 36 for the IMI arm and 1, 12 and 24 for the DEI arm). Similar models were performed for other trial outcomes; only the dependent variable was changed. Statistical significance was set at $p < 0.05$.

RESULTS

According to the initial protocol, the estimated sample size to detect a significant difference in visual ability measured with the activity inventory at 12 weeks was 22 per arm [38]. A total of 59 patients were invited to participate; of these, 46 agreed to take part in the study. Socio-demographic and clinical characteristics of the 46 participants who accepted to take part in the study are summarized in Table 1.

Table 1 Socio-demographic characteristics of the participants at baseline, dropouts included

Variable	Arm	
	IMI	DEI
N	23	23
Age, mean (SD), in years	72.61 (13.00)	70.08 (8.74)
Comorbidities, mode (range)	2 (5)	4 (6)
Years with VI, mean (SD), in years	2.72 (1.85)	3.64 (3.79)
Presenting VA better eye, mean (SD), in logMAR	0.71 (0.20)	0.66(0.30)
Sex:		
Sex: Female, *n* (%)	10 (43%)	15 (63%)
Sex: Male, *n* (%)	13 (57%)	9 (37%)
Main diagnosis:		
Main diagnosis DR, *n* (%)	16 (70%)	18 (78%)
Main diagnosis AMD, *n* (%)	7 (30%)	5 (22%)
Living:		
Living: with others, *n* (%)	19 (82.6%)	21 (91%)
Living: alone, *n* (%)	4 (17.4%)	2 (9%)
Education:		
Education: $\leq$ 4 years, *n* (%)	9 (39%)	9 (39%)
Education: 6 to 9 years, *n* (%)	8 (35%)	11 (48%)
Education: 12 years *n* (%)	4 (17%)	1 (4%)
Education: University or more, *n* (%)	2 (9%)	2 (9%)

IMI immediate intervention arm, *DEI* delayed intervention arm, *VA* visual acuity, *VI* visual impairment, *SD* standard deviation

For the duration of the study, which was mostly conducted during the COVID-19 pandemic, there were ten dropouts (21%) related to non-adaptation to the low vision aids, vision improved because of medical treatments or participants failed to show at follow-up assessments. Dropouts were participants that failed to complete the first follow-up after they received the intervention.

The time with the optometrist during the vision rehabilitation intervention was approximately 90 min (questionnaire administration excluded). The reading aids prescribed comprised a total of 17 new pairs of glasses (3 for distance and 14 for near) and 23 LED-illuminated handheld magnifiers. The mean power of the reading aids was 10.0D (SD = 5.0), the median for near glasses was 6D and 12D for the handheld magnifiers.

Main Outcome Measure of the Trial—Visual Ability

The mean visual ability in the IMI (n = 23) before the intervention at baseline or week 1 was 0.28 logits (SD = 1.14), and it increased (n = 21 at 12 weeks) to 0.91 logits (SD = 1.24)

after the intervention. In the DEI group ($n = 23$), the mean visual ability at baseline (week 1) was 0.71 logits (SD = 1.30), and it changed ($n = 16$ at 12 weeks) to 0.45 logits (SD = 8.88) after the waiting period. A LMM with visual ability as dependent variable revealed a main effect of time, given in weeks ($F(3, 69) = 41.16$, $p < 0.001$), and an interaction time × arm ($F(1,69) = 6.54$, $p = 0.012$). The effect of arm was not statistically significant ($p = 0.059$). Comparisons within and between arms are summarized in Table 2; bold p-values correspond to the main results of the trial after 12 weeks, whose values are shown in Fig. 1.

Clinical Changes with Rehabilitation

Descriptive statistics for visual outcomes are given in Table 3. A LMM with VA in the better-seeing eye as dependent variable revealed a statistically significant effect for factor time ($F(3,69) = 3.63$, $p < 0.017$); the effects of interaction time × arm ($p < 0.54$) and factor arm ($p = 0.07$) were not statistically significant. These results show that distance acuity in the better-seeing eye improved with time for both arms.

LMM for near VA as dependent variable revealed statistically significant effect of main factor time ($F(3,69) = 49.77$, $p < 0.001$) and for interaction time × arm ($F(1,69) = 82.61$, $p < 0.001$), the effect of arm was not statistically

Table 2 Summary of the pairwise comparisons for the interaction time × arm and the AI changes within arm over time

Arm	Week	Arm	Week	MD	SE	DF	*t* Value	Pr >|*t*|	Adj	Adj *P*
DEI	1	DEI	12	− 0.1024	0.1199	69	− 0.85	0.3963[A]	T-K	**0.9560**
DEI	1	DEI	24	− 0.6480	0.07298	69	− 8.88	< 0.0001	T-K	< 0.0001
DEI	1	IMI	1	0	0.1130	69	− 0.00	1.0000	T-K	1.0000
DEI	1	IMI	12	− 0.5233	0.1157	69	− 4.52	< 0.0001	T-K	0.0003
DEI	1	IMI	36	− 0.6872	0.1170	69	− 5.88	< 0.0001	T-K	< 0.0001
DEI	12	DEI	24	− 0.5457	0.1255	69	− 4.35	< 0.0001	T-K	0.0006
DEI	12	IMI	1	0.1024	0.1225	69	0.84	0.4065	T-K	0.9599
DEI	12	IMI	12	− 0.4210	0.1250	69	− 3.37	0.0012[C]	T-K	**0.0151**
DEI	12	IMI	36	− 0.5848	0.1262	69	− 4.63	< 0.0001	T-K	0.0002
DEI	24	IMI	1	0.6480	0.1192	69	5.44	< 0.0001	T-K	< 0.0001
DEI	24	IMI	12	0.1247	0.1217	69	1.02	0.3092	T-K	0.9082
DEI	24	IMI	36	− 0.03915	0.1230	69	− 0.32	0.7512	T-K	0.9995
IMI	1	IMI	12	− 0.5233	0.1128	69	− 4.64	< 0.0001[B]	T-K	**0.0002**
IMI	1	IMI	36	− 0.6872	0.1020	69	− 6.74	< 0.0001	T-K	< 0.0001
IMI	12	IMI	36	− 0.1638	0.06762	69	− 2.42	0.0180	T-K	0.1628

The comparisons indicate that the differences between week 1 and week 12 for DEI (comparison A) were not statistically significant whilst the differences were statistically significant for the IMI after the intervention (comparison B) and the groups showed statistically significant differences (comparison C)

MD mean difference for the AI between the pair group-week in the first two columns and the pair arm-week in column 3 and 4. *SE* standard error for the MD, *T-K* Tukey-Kramer procedure, *IMI* immediate intervention group, *DEI* delayed intervention group

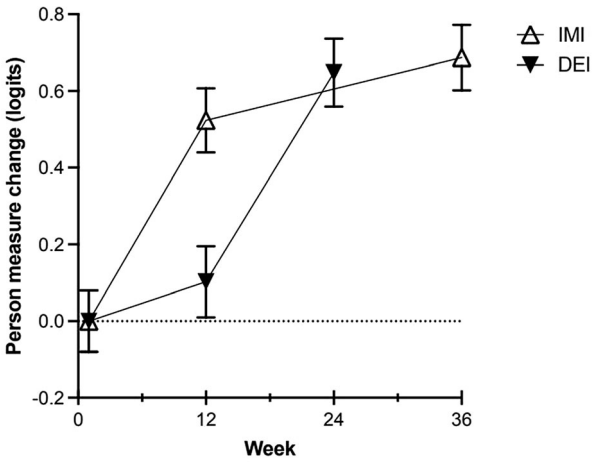

Fig. 1 Estimated mean AI change and standard errors for the change for both groups over time. IMI = immediate intervention group, DEI = delayed intervention group. This cross-over design uses the DEI group as control group—between weeks 1 and 12; DEI group was on a waiting list for a low vision intervention but did not receive it. The IMI group received a low vision rehabilitation intervention at week 1 and AI changes were assessed at 12 weeks—that assessment corresponds to the main outcome of the trial. Between weeks 12 and 36 weeks the IMI group did not receive any attention and this assessment at 36 weeks was performed to investigate whether the benefits of the rehabilitation persisted

significant ($p = 0.45$). These results show that near acuity improved with time for both arms but the interaction indicates that the changes were due to the intervention that was delivered at different time points to each arm.

For contrast sensitivity as dependent variable, none of the effects tested with LMM was statistically significant. For critical print size as dependent variable, the main effect time in weeks was statistically significant ($F(3,53) = 77.82$, $p < 0.001$). These findings reveal that the intervention failed to improve contrast sensitivity but succeeded at improving critical print size.

Results of the Economic Evaluation

Effectiveness and Costs of the Intervention

The intervention was effective at providing additional QALYs. Using the EQ-5D-5L index value, for the IMI group the median QALY gain of 0.102 (IQR = 0.169) after 12 weeks was statistically significant (Wilcoxon test, $Z = -2.670$, $p = 0.008$). The median QALY change of 0.00 (IQR = 0.287) for the DEI group during the 12 weeks waiting was not statistically significant ($p = 0.477$). The difference in effect between groups (effect = (EQ-5D-5L index value at 12 weeks) minus (EQ-5D-5L index value at week 1) for each participant) at 12 weeks was statistically significant (Mann-Whitney U test, $Z = -2.007$, $p = 0.045$).

Using near acuity ophthalmic utility values, for the IMI group the mean improvement in QALY of 0.077 (SD = 0.072) after 12 weeks was statistically significant (paired t-test $t(20) = -5.217$, $p < 0.001$.) The mean reduction in QALY of − 0.008 (SD = 0.041) after 12 weeks for the DEI was not statistically significant ($p = 0.490$). The difference in effect between groups at 12 weeks was statistically significant (independent t-test, $t(36) = 4.611$, $p < 0.001$).

The mean cost of the intervention was €118.79 (SD = 24.37), range = €103.12–€199.27. The costs of the intervention included €31.23 for hospital costs for each participant, the mean cost for distances glasses was €84 and the mean cost for near aids (near glasses or LED-illuminate handheld magnifiers) was €80.71 (SD = 7.87).

Cost-Effectiveness Results

Table 4 summarizes the effect and ICER results for the 5000 bootstrap replications. The mean ICER obtained through the EQ-5D-5L index value was 30,421€/QALY and the median was 23,054€/QALY. These values show that the intervention is cost-effective assuming a threshold equal to 2 × the Portuguese per capita GDP, that is, €38,862. The mean ICER obtained through near acuity ophthalmic utility value was 1186€/QALY and the median was 1184€/QALY, which shows that the intervention can be considered cost-effective assuming a threshold equal to one time the Portuguese per capita GDP of €19,431.

Figure 2 shows the cost-effectiveness planes and the cost-effectiveness acceptability curves. In Fig. 2A the points are spread between an incremental effect on the x-axis of − 0.20 and + 0.20, while on Fig. 2B all the points show an incremental effect on the x-axis above 0. The

Table 3 Vision outcomes for IMI and DEI at different time points

Time point and arm	Vision outcome				
	Distance VA better eye (logMAR)	Distance VA worst eye (logMAR)	Near VA (logMAR)	Contrast sensitivity (logCS)	Critical print size (logMAR)
Week 1					
IMI**					
Mean (SD)	0.70 (0.20)	1.04 (0.43)	0.77 (0.20)	1.32 (0.19)	1.00 (0.16)
Median (IQR)	0.66 (0.30)	0.92 (0.56)	0.70 (0.30)	1.28 (0.24)	1.00 (0.20)
DEI**					
Mean (SD)	0.61 (0.17)	1.02 (0.59)	0.62 (0.19)	1.36 (0.21)	nm
Median (IQR)	0.56 (0.26)	0.85 (0.72)	0.60 (0.26)	1.40 (0.32)	nm
Week 12					
IMI					
Mean (SD)	0.66 (0.20)	1.02 (0.43)	0.32 (0.10)	1.43 (0.16)	0.54 (0.15)
Median (IQR)	0.62 (0.32)	0.94 (0.62)	0.36 (0.16)	1.44 (0.20)	0.50 (0.10)
DEI**					
Mean (SD)	0.63 (0.21)	1.04 (0.61)	0.66 (0.20)	1.36 (0.25)	0.97 (0.16)
Median (IQR)	0.58 (0.24)	0.85 (0.61)	0.64 (0.22)	1.40 (0.36)	0.90 (0.20)
Week 24					
DEI					
Mean (SD)	0.58 (0.19)	1.03 (0.61)	0.25 (0.11)	1.45 (0.19)	0.51 (0.15)
Median (IQR)	0.50 (0.17)	0.89 (0.93)	0.24 (0.18)	1.50 (0.21)	0.50 (0.20)
Week 36					
IMI					
Median (IQR)	0.68 (0.19)	1.05 (0.42)	0.36 (0.09)	1.33 (0.28)	0.61 (0.10)
Median (IQR)	0.66 (0.32)	1.04 (0.46)	0.38 (0.12)	1.40 (0.24)	0.60 (0.10)

nm note measured, *IMI* immediate intervention arm, *DEI* delayed intervention arm, *VA* visual acuity, *SD* standard deviation, *IQR* interquartile range

**Measurements performed with the habitual correction ("presenting vision outcomes")

Table 4 Economic analysis: incremental effect and cost and ICER estimation from bootstrapping

Utility computation	Incremental effect Mean difference (95%CI)	Incremental cost in € Mean difference (95%CI)	ICER in €/QALY Estimate ICER (95%CI)
EQ-5D-5L index	0.0039 (− 0.0927, 0.0931)	118.72* (110.75, 128.27)	30,421.70 (21,737.41–50,744.77)
Near VA value	0.1001 (0.0679, 0.1346)		1186.20 (1181.12–1191.34)

CI confidence interval, *ICER* incremental cost-effectiveness ratio, *VA* visual acuity, *QALY* quality-adjusted life years
*This value for incremental costs is the result of bootstrapping and because of that can be different from the obtained during the trial and given in the text

northeast quadrant is where the intervention is more costly but more effective and the northwest quadrant is where the intervention is more costly but less effective. Figure 2C shows that the probability of the intervention to be cost-effective is 49% for a threshold of ~ €20,000 (Portugal per capita GDP) and Fig. 2D shows that the probability of the intervention to be cost-effective is 100% from a threshold of €2400. Table 5 summarizes the sensitivity analysis based on different cost scenarios; the intervention remains cost-effective in all cost scenarios.

DISCUSSION

In the current study we investigated the effect of a basic vision rehabilitation intervention and its cost-effectiveness. The study took place in a public hospital and was focused on a single interaction with an optometrist providing updated refractive correction, reading aids, basic training with the aid and instructions to reduce the effect of low vision in activities of daily living. The ability to perform activities that rely on vision—visual ability—was the main outcome measure and was assessed with the AI. As hypothesized, a basic vision rehabilitation intervention resulted in a significant improvement in visual ability. These results are in line with previous studies conducted in other countries [4, 18, 21, 55, 59–61]. In addition, there was an improvement in health-related quality of life as measured by the EQ-5D-5L, which is also in line with other studies [37, 60, 61]. The current basic vision rehabilitation intervention was cost-effective, which is in line with studies investigating the cost-effectiveness of other types of rehabilitation interventions for people with VI [55, 56, 62–64].

Clinical Impact of Rehabilitation

The improvement observed in our participants' visual ability suggests that they experienced fewer difficulties performing activities of daily living, which provides evidence of the benefits of vision rehabilitation for people with vision impairment [4, 5, 59]. The difference between the current study and previous studies is that others tended to included comprehensive rehabilitation with different professionals (e.g., occupational therapist, social worker) and multiple interactions with the patients to improve aspects such as mobility or at home training [4, 5, 59, 65, 66]. Therefore, the current study gives fresh evidence that a simple but structured intervention produces measurable improvements in everyday functioning for people with VI.

Improvements in visual ability can be explained by an overall improvement in vision function and, eventually, an optimization of the remaining vision. The improvement in acuity at distance (overall approximately 2 letters) can be considered modest but reasonable if we consider that with some treatments such as anti-VEGF injections the improvement in distance VA is in the range 1–5 letters [67, 68]. Most of our participants were unable to read common print sizes, such as personal mail, before rehabilitation. In line with the initial expectations, the intervention caused significant improvements in near VA and critical print

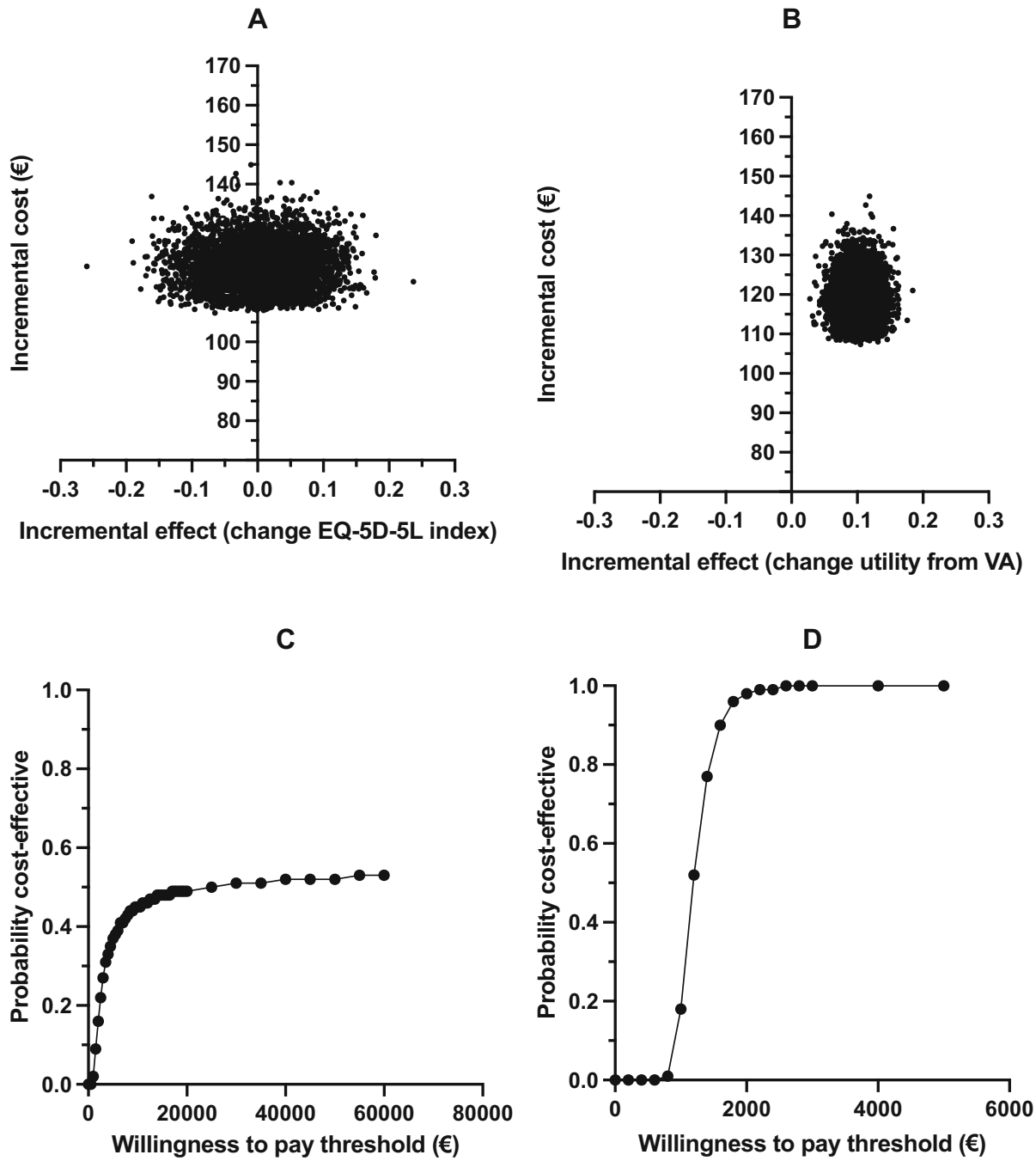

Fig. 2 Top row: cost-effectiveness planes: **A** based on EQ-5D-5L and **B** based on near VA. Bottom row, cost-effectiveness acceptability curves, **C** based on EQ-5D-5L and **D** based on near VA, generated from cost and effectiveness data

size, which reduced the reading difficulties reported in the AI [18, 21, 37, 69–71]. In short, changes in visual ability detected after the basic vision rehabilitation intervention can be explained by improvements in near vision tasks achieved with the correct use of the prescribed magnification.

Table 5 Sensitivity analysis adjusted by cost

Basis for utility computation	Real cost ICER in €/*QALY*	Lowest cost ICER in €/*QALY*	Highest cost ICER in €/*QALY*
EQ-5D-5L index value			
Median	1118.82	1015.96	2174.38
Mean	9977.54	8501.24	18,194.56
Near vision ophthalmic utility value			
Median	1336.00	1213.18	2596.47
Mean	1434.32	1222.09	2615.55

QALY quality-adjusted life years, *ICER* incremental cost-effectiveness ratio, *VA* visual acuity

Cost-Effectiveness—Discussion of the Economical Evaluation

The cost of the basic vision rehabilitation intervention was lower than the costs reported by other studies [33]. These results can be explained by the normal differences in costs of the healthcare workforce and products in different countries. Bray et al. found that interventions for near vision activities tend to be cost-effective independently of the type of magnifiers [55]. Our findings are in line with these results.

ICER calculations for different utilities in Table 4 and cost scenarios in Table 5 revealed that our intervention was always cost-effective assuming a threshold equal to two times the Portuguese per capita GDP. The World Health Organisation's Commission on Macroeconomics in Health suggested that cost-effectiveness thresholds should be three times the per capita GDP [72], which gives a cost–effectiveness threshold of €58,293. However, when using the EQ-5D-5L index we found that the probability of the intervention to be cost-effective was roughly 49% (for a threshold equal to the Portuguese per capita GDP) and 52% (for a threshold equal to two times the Portuguese per capita GDP)—which indicates uncertainty around these estimates (Fig. 2A). Based on the near vision ophthalmic utility value, the intervention was more cost-effective than with the EQ-5D-5L index value and there was less uncertainty around the estimates (Fig. 2B). This may be related to the fact that the near acuity-based ophthalmic utility value captures the actual near vision improvements. The EQ-5D-5L index has been considered to have low responsiveness to the effects of vision rehabilitation; therefore, our results for the cost-effectiveness have limitations [38, 73]. The fact that we used the EQ-5D-5L, an instrument with limited responsiveness to vision rehabilitation, is a limitation to the results of the current trial [74].

A literature review concluded that most ophthalmologic interventions are cost-effective and the median cost-utility value is 5 219$/QALY (~ 4571€/QALY) [75]. Recent findings in vision rehabilitation services in England found that for values between £13,000 (~ €15,423) and £30,000 (~ €35,591) per QALY, in-house VR had a high probability of being cost-effective from a social care perspective. However, the probability of being cost-effective was lower when a healthcare perspective was used [62]. Assuming a healthcare perspective, which is expected to capture only part of the benefits of vision rehabilitation, the basic intervention performed as part of the current study can be considered cost-effective as shown by the different costs and utility scenarios investigated.

We consider that the COVID-19 pandemic was a significant barrier for recruiting and retaining participants in this study, which led to its first limitation—the *n* was less than expected and can be considered small. The small sample

affected particularly the cost-effectiveness analysis where results for QALY gains and losses for the groups were very "noisy"—this limits the strength of the findings. Another limitation was the fact that the research person collecting the data (author LHM) was not "blinded" for the allocation of the participants. That might have caused bias during data collection; however, the researcher was always aware of this fact and did everything possible to control any bias. These limitations should be addressed in future studies. A further issue that can be hard to address in studies like the current one is the fact that patients at need of VR also need medical care during rehabilitation. We discussed with the ophthalmologists responsible for the patients' treatments what they expected in terms of visual prognosis during the temporal frame of the study for each of the participants. None was expected to improve visual function. However, treatments to prevent vision loss such as intravitreal injections were given, if necessary, during patients' participation in the current study. For example, one of the dropouts was submitted to a vitrectomy that improved visual acuity significantly. Acuity of most participants remained stable during the time that they were in the study, as shown by the vision outcomes given in Table 3.

CONCLUSION

Results of the current study show that a basic vision rehabilitation intervention was clinically impactful and cost-effective. A single patient-optometrist interaction led to immediate meaningful improvements for the patient that were retained over time. These findings are important to clinical and rehabilitation practices and for planning vision rehabilitation services. We hope that results of the current study provide the necessary basis for the development of VR services in Portugal that follow at least the minimum standards established by WHO Package of Eye Care Interventions.

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informed consent for participation in this study. The study conformed to the tenets of the Declaration of Helsinki.

Data Availability. The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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