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Cross-sectional study investigating the prevalence and causes of vision impairment in Northwest Portugal using capture–recapture

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ABSTRACT

Objectives The aim of this study was to estimate the prevalence and causes of vision impairment (VI) in Portugal.

Setting Information about people with VI was obtained from primary care centres, blind association (ACAPO) and from hospitals (the PCVIP study) in the Northwest of Portugal during a period spanning years 2014–2015. Causes of VI were obtained from hospitals.

Participants Administrative and medical records of people with visual acuity in the better seeing eye of 0.5 decimal (0.30logMAR) or worse and/or visual field less than 20° were investigated. Capture–recapture with log-linear models was applied to estimate the number of individuals missing from lists of cases obtained from available sources.

Primary and secondary outcome measures Log-linear models were used to estimate the crude prevalence and the category specific prevalence of VI.

Results Crude prevalence of VI was 1.97% (95% CI 1.56% to 2.54%), and standardised prevalence was 1% (95% CI 0.78% to 1.27%). The age-specific prevalence was 3.27% (95% CI 2.36% to 4.90%), older than 64 years, 0.64% (95% CI 0.49% to 0.88%), aged 25–64 years, and 0.07% (95% CI 0.045% to 0.13%), aged less than 25 years. The female-to-male ratio was 1.3, that is, higher prevalence among females. The five leading causes of VI were diabetic retinopathy, cataract, age-related macular degeneration, glaucoma and disorders of the globe.

Conclusions The prevalence of VI in Portugal was within the expected range and in line with other European countries. A significant number of cases of VI might be due to preventable cases and, therefore, a reduction of the prevalence of VI in Portugal seems possible. Women and old people were more likely to have VI and, therefore, these groups require extra attention. Future studies are necessary to characterise temporal changes in prevalence of VI in Portugal.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Medical records and registers of people with vision impairment were used to determine the number of cases in these sources.
⇒ Data from three sources (lists) with records about people with vision impairment were combined using log-linear models to determine the number of 'uncaptured' cases.
⇒ Capture–recapture methods were used to determine the prevalence of vision impairment in the Northwest Portugal.
⇒ Capture–recapture methods to compute prevalence are more accurate than pure case counting from lists and more affordable than cross-sectional studies.
⇒ A limitation of the current study was the low completeness, that is, the number of cases captured compared with the number of uncaptured cases.

INTRODUCTION

Vision impairment (VI) leads to a significant loss of quality of life mostly due to activity limitations, loss of independence and difficulties to find jobs.[1–6] Because VI leads to a significant burden it is important to have regular vigilance (estimates) of cases of VI so that the quality of eye care and events such as diseases that may be leading to more cases of VI can be detected, evaluated, monitored and, eventually, vision loss can be prevented.[7 8] One example of initiatives based on prevalence was VISION 2020—an action of the WHO and the International Agency for the Prevention of Blindness, whose aim was to prevent and monitor VI and promote vision rehabilitation worldwide.[9] Recent estimates indicate that VI remains a significant health problem in Europe; although, in some countries reliable and updated information is lacking.[9]

In 2020, in Western Europe, it has been estimated that there were 15 million people with moderate or severe VI.[9] However, the prevalence of VI and the methodology for the estimation varies significantly from country to country. For example, a population-based study conducted in Denmark in 2016 defined VI as best corrected visual acuity worse than 20/40 (0.3 logMAR) in the better-seeing eye.

The study involved people aged 20–94 years and found a prevalence of 0.4% (95% CI 0.2% to 0.7%).[10] A very different estimation with significantly different values was performed France in 2005,[11] in France VI was self-reported and the prevalence was 1.95%. In 2007 and for the population aged 50 years or older, a study from Hungary reported a prevalence of 0.5% (95% CI 0.2% to 0.7%) for severe VI and 5.1% (95% CI 4.3% to 5.9%) for moderate VI.[12] These numbers are often hard to compare due to different age categories included and recruitment methods used; although, they point to differences among European nations.

Differences in prevalence of VI within Europe, as summarised in table 1, may be due to not only study design but also, for example, due to differences in disease prevalence. VI and blindness in Western Europe are mostly linked to age-related eye diseases. In Germany, for example, that corresponds to 70% of all cases of blindness.[13] In Scotland the leading causes of VI are age-related macular degeneration (AMD), glaucoma, diabetic retinopathy (DR), myopic degeneration and optic atrophy.[14] Differences in disease prevalence and disease severity are associated with factors such as prevention and access to treatments.[8] Inequalities in accessing treatments can be seen even within a single country such as Portugal where unequal access to anti-vascular endothelial growth factor (anti-VEGF) injections has been detected.[15] This makes it important to investigate prevalence and causes of VI as detailed as possible at national and regional levels. One method to study prevalence when cross-sectional studies of the population are unavailable is called capture–recapture (CR).

CR methods have been used to estimate the prevalence of several eye conditions.[16–24] CR methods are a methodology that can overcome the problem of cases that are never captured by, for example, registers for the visual impaired.[25–27] For a detailed description on how to use CR methods we recommend reading our review about the method.[28] Due to the lack of information about the prevalence of VI in Portugal, we conducted a study with CR methods using data from different sources. The aim of this study was to estimate the prevalence and the main causes of VI in Portugal using CR methods.

METHODS

Information about people with VI was obtained from different sources in the Northwest of Portugal during a period spanning years 2014–2015. The geographical coverage included 42 municipalities from two provinces: Minho, population density=241.1 inhabitants/km^2 and Douro Litoral, population density=742.4 inhabitants/km^2 as reported by national CENSUS 2011.[29]

Possible sources of patients with visual acuity in the better eye of 0.5 decimal (0.30logMAR) or worse and/or visual field less than 20 degrees were investigated.[30] The first source were primary care centres that were used for list L1. This list contained subjects that applied, for

Table 1 Prevalence of visual impairment in European countries

Country	Year	Sample	VI definition	Prevalence
Denmark[10]	2016	3826 participants aged 20–94 years old from the Danish General Suburban Population Study	The best-corrected visual acuity worse than 20/40 in the better-seeing eye	0.4% (95% CI 0.2% to 0.7%)
Hungary[12]	2017	105 clusters of 35 people 50 years of age or older	SVI-VA<6/60–3/60 MVI- VA<6/18–6/60	SVI, 0.5% (95% CI 0.2% to 0.7%) MVI, 5.1% (95% CI 4.3% to 5.9%)
France[11]	2005	Random stratified sample of 359 010 French citizens	Self-reported visual impairment	1.95%
Spain[43]	2014	213 626 participants aged ≥15 years from a 2008 Spanish Survey	Distance and near visual impairment distinguished by applying a questionnaire	Near visual impairment –1.89% Distance visual impairment –1.89%
Germany[7]	2019	Population-based cohort study in Germany concerning 14 687 adults aged 35–74	Acuity below 0.3 in the better-seeing eye	0.37% (95% CI 0.28% to 0.49%)
Iceland[1]	2008	Random sample of 1045 citizens of Reikjavik aged 50 or more years	Bilateral VI—best-corrected visual acuity VA <6/18 or visual field of >or = 5° and <10° around the fixation point in the better eye	0.96% (95% CI 0.37% to 1.55%)
UK[67]	2002	14600 participants aged 75 years and older	Binocular visual acuity <6/18	12.4% (95% CI 10.8% to 13.9%)

MVI, moderate visual impaiment; SVI, severe visual impairment; ; VA, visual acuity.

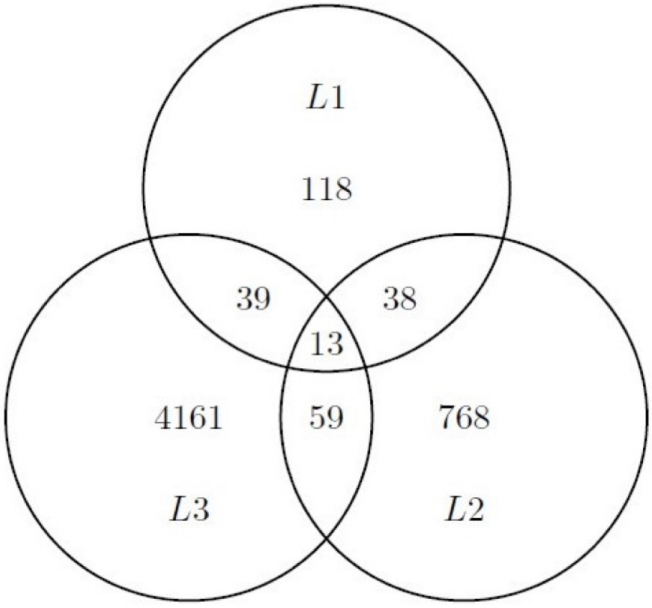

Figure 1 Venn diagram representing the intersection between the three lists.

example, for medical certificates of VI. According to the Portuguese law people with a level of impairment of 60% or more are entitled to, among other, tax exemption, completely free healthcare or early retirement.[31] As an example, to get a degree of 60% or more from vision only, one eye must have no measurable acuity and the other can have acuity up 0.2 decimal.[32] Although, for this certificate all types of impairments can be combined, for example vision and motor impairments, to reach the final score. Because of that, cases mapped as having VI were analysed and only those with field or acuity matching the inclusion criteria were included in this study. The second source used was an association for the visually impaired named ACAPO and their records were used in the second list L2. To be member of Associacao dos Cegos e Ambliopes de Portugal (ACAPO) people must be visually impaired (low vision or blind).

The third list L3 was obtained from the Prevalence and Costs of Visual Impairment in Portugal study (PCVIP-study), a hospital-based study whose aim was to determine prevalence, causes and costs of VI in Portugal.[33–35] The study gathered demographic, clinical and socioeconomic information of people with VI. Participants were selected among patients attending ophthalmologists' appointments at four Portuguese public hospitals: Hospital de Braga, Hospital Senhora da Oliveira-Guimarães, Hospital de Santa Maria Maior-Barcelos and Centro Hospitalar e Universitário de São João-Porto. The initial database included people with acuity 0.5 decimal (0.30 logMAR) or worse. To make compatible with the definition of VI in the ICD9[30] and with the acuity in the other lists only cases with visual acuity below 0.3 decimal (0.5 logMAR) in the better-seeing eye were used for the estimation of prevalence.

Table 2 Number of individuals presenting each possible capture history

L1	L2	L3	Freq
1	1	1	13
1	1	0	38
1	0	1	39
0	1	1	59
1	0	0	118
0	1	0	768
0	0	1	4161
0	0	0	x

All lists had variables that allowed assessment of repeated cases by using a string or combination of strings that form identifiers or 'tags'. Information available included: initials, date of birth, sex and municipality. The list from the hospitals also included information about the cause of VI. An example of a tag could be JS130519802, where JS are the initials (first and last name), digits 13051980 correspond to the date of birth (13-05-1980) and the last digit (2) defines sex—2 is a female in the example given. By matching the identity strings (tags) of the three lists, it was possible to ascertain the number of individuals present in all three lists and the number of individuals present at any combination of two lists.

Application of the CR method

To be used in CR lists need to be obtained at approximately the same time, or based on different sources that represent approximately the same population.[36] In addition, to obtain reliable results with CR certain assumptions need to be meet: (1) the sources of lists are independent—this implies that the probability of a subject being in both list A and list B equals the product between the probability of being in A alone and the probability of being in B alone,[37] (2) the probability of association within each source (catchability) is equal for all individuals—the probability may vary from one list to another, or be constant overall,[37 38] (3) the population is closed (no births, deaths or migrants). These assumptions are restrictive and, when applied to medical conditions, are unlikely to be strictly followed. Log-linear models are one way of handling, for example, lists that are not completely independent.[37]

Log-linear models were applied to estimate the number of individuals missing from all three lists.[38] Log-linear models result from the application of Poisson regression models to table 2 which summarises all possible capture history for all cases listed. The capture histories are illustrated in figure 1. The logarithm of the count in each cell of the table is modelled as a linear function with terms indicating the presence or absence in the lists and terms modelling possible pairwise dependences between lists. Log-linear models compute the expected value of n_{ijk}, that is, the expected value for the number of individuals with capture history $(i\ j\ k)$. For example, according to table 2

or figure 1, $n_{111} = 13$. When there are three lists and there is no simultaneous dependence amongst the three but a dependence between any possible pair of lists the equation for the log-linear model is:

$$\log E(n_{ijk}) = \begin{array}{l} u_0 + u_1 I(i=1) + u_2 I(j=1) + u_3 I(k=1) + u_{12} I(i=j=1) \\ +u_{13} I(i=k=1) + u_{23} I(j=k=1) \end{array} \quad (1)$$

In equation 1, $I(\mathrm{i}=1)$ stands for the function that assigns 1 to the capture histories (1 j k) and 0 to all the others. The parameter u_{12} models the dependence between lists 1 and 2, and u_{13} the dependence between lists 1 and 3 and equivalent to other pairs. By using equation 1, we can compute the expected value for the number of individuals with capture history (i j k), that is, $\mathrm{E}(n_{ijk})$.

The parameters of the model can be computed using the R package Rcapture.[39 40] For example, using equation 1, the software can compute the expected value for the number of individuals with capture history (1 1 1), that is, $E(n_{111})$ and compares the model estimation with the true value of n_{111}, in our case the real intersection would be 13 cases (figure 1). This process can be repeated for all capture histories except for (0 0 0) which are the missing cases (hidden population). Then the null hypothesis can be tested, that is, 'the observed cell counts are equal to the estimated cell counts'. In other words, 'does the model fits the data well'?—that is given by the χ^2 goodness of fit test. After modeling all possible parameters, the Rcapture software can use equation 1 to compute $E(n_{000})$ and that is the size of the hidden population. The final estimate for $E(n_{000})$ is given by the best model that should pass the χ^2 goodness of fit test and should be the one with the lowest value of AIC.[41] A review of the method with an intuitive link to a video (https://www.youtube.com/watch?v=aiSKgIc_8vk) is given in a review by Bird and King[42] and in our previous publication.[28]

After choosing the best possible model for our data we obtained an estimate of the size of the hidden population and consequently we estimate of the number of individuals with VI. The same procedure was used to compute category specific prevalence according to age and sex. Within each category several models were applied to sublists obtained from the main lists.

Patient and Public Involvement

Members of the association ACAPO were involved in the design and data collection of this study.

RESULTS

The total number of inhabitants in the geographical area covered by the current study was 3 010 964. The list from primary care centres (L1) had 208 cases (52% females) with a mean age of 60 years (SD=18.93). The list with the cases from ACAPO (L2) had 878 cases (43% females) with a mean age of 54 years (SD=18.0). The list from the hospitals (L3) had 4272 cases (58% females) with a mean age of 74 years (SD=18.0). The Venn diagram in figure 1 shows the intersection between lists obtained after matching identity strings. Figure 1 shows that, for example, 39 individuals were in L3 and L1 and were not in L2; 13 individuals were in all three lists; 4161 individuals were only in L3. Table 2 provides the possible capture histories and the number of individuals with that history. For example, a subject has a capture history (1 1 0) when she or he was in L1 and L2 but not in L3.

Log-linear models assuming possible list dependence scenarios were applied to model the counts in table 2. The model is expected to estimate the value of x (see also table 2) that corresponds the number of individuals with capture history (0 0 0). That is, the size of the hidden population or the number of individuals not captured by any of the three lists. The estimate of total number of people with VI (N) was given by the expression: N= x+13+38+39+59+118+768+4162, the value of N changes from model to model because the estimates obtained to the unknown x value. All possible list dependence scenarios were considered resulting in seven models summarised in table 3. Code used to implement these

Table 3 All possible log-linear models and resulting prevalence estimates

List Dependence	N	N–	N+	Prevalence	AIC	P value (X^2 goodness of fit test)
L1L2 L2L3	17754	14017	23467	0.60% (95% CI 0.47 to 0.79)	74.28	<0.001
L2L3	11781	10200	13888	0.40% (95% CI 0.34 to 0.47)	142.10	<0.001
L1L3 L2L3	7682	6931	8835	0.26% (95% CI 0.23 to 0.30)	109.86	<0.001
L1L2 L1L3	59316	47038	76590	1.97% (95% CI 1.56 to 2.54)	58.59	0.92
L1L2	41042	34713	49157	1.38% (95% CI1.17 to 1.65)	105.25	<0.001
L1L3	36608	30991	43820	1.23% (95% CI 1.04 to 1.47)	234.08	<0.001
All independent	29587	25833	34201	0.98% (95% CI 0.86 to 1.14)	252.58	<0.001

When we write, for example, L1L2, we are indicating that the model assumed dependence between L1 and L2. N– and N+ represent lower and upper estimates of N according to a 95% CI. P values test the hypothesis of the model fitting well (a value above 0.05 is indicative that the difference between the model predictions and the data are not statistically significant) the data and the AIC is a criterion to choose between models by considering a balance between the number of fitted parameters and the maximum likelihood.
AIC, Akaike's information criteria.

Table 4 Age-specific prevalence and sex-specific prevalence

Age-specific prevalence			
Age	**Prevalence**	**AIC**	**P value (χ^2 goodness of fit test)**
<25	0.07% (95% CI 0.045 to 0.13)	22.37	0.94
25-64	0.64% (95% CI 0.49 to 0.88)	53.94	0.77
>64	3.27% (95% CI 2.36 to 4.90)	50.43	0.82
Sex-specific prevalence			
Sex	**Prevalence**	**AIC**	**P-value (χ^2goodness of fit test)**
Male	1.67% (95% CI 1.32 to 2.19)	28.85	1
Female	2.20% (95% CI 1.65 to 3.08)	28.58	1

P values test the hypothesis of the model fitting well (a value above 0.05 is indicative that the difference between the model predictions and the data is not statistically significant) the data and the AIC is a criterion to choose between models by considering a balance between the number of fitted parameters and the maximum likelihood.
AIC, Akaike's information criteria.

models in R Statistics (V.3.6.1), package Rcapture[39 40] is provided in an online supplemental appendix A.

The list dependence scenario L1L2 and L1L3 generated a model fitting the data well, χ^2 goodness of fit test $Pr\left(\chi^2_1 \geq 0.009\right) = 0.92$, and corresponds to the model:

$$\log E(n_{ijk}) = \begin{array}{l} u_0 + u_1 I(i=1) + u_2 I(j=1) + u_3 I(k=1) + u_{12} I(i=j=1) \\ +u_{13} I(i=k=1) \end{array} \quad (2)$$

According to the model given by equation 2 the crude prevalence of VI as estimated in this study was 1.97% (95% CI 1.56% to 2.54%). The standardise prevalence was 1% (95% CI 0.78% to 1.27%).

Completeness, that is, the proportion of the population with VI that has been captured by our three lists, assuming that the size N of the population with VI was 59 316, was 9%. Completeness was computed using the formula below, in the formula, n_{100} is the number of cases with capture history (1 0 0) and the meaning is the same for all other parcels such as n_{010}i n the denominator of the fraction.

$$\frac{n_{100}+n_{010}+n_{001}+n_{111}+n_{101}+n_{011}+n_{110}}{\hat{N}} \times 100$$

Table 4 summarises the category specific prevalence according to age and according to sex. To run new log-liner models for each category we divided the initial lists according to the desired categories. Subsamples for each category were used to generate new Venn diagrams. Log-linear models for each subsample were set as given in table 3, that means seven different dependency scenarios for each, for example, age category. The best model was chosen using χ^2 goodness of fit tests and AIC.

Table 5 summarises the distribution of causes of VI. This information was available from L3 (from the hospitals), causes were classified according to the ICD9. DR was the most common cause of VI with 31% (95% CI 29% to 32%) of the cases in L3, followed by cataract 15% (95%

Table 5 Summary of the causes of visual impairment, bold font highlights the mains causes for each age group

Causes of visual impairment	Less than 25 years	25–64 years	More than 64 years	All ages combined
	N (%)	N (%)	N (%)	N (%)
Age-related macular degeneration	---	29 (4)	550 (17)	579 (14)
Cataract	10 (7)	58 (7)	592 (18)	660 (15)
Chorioretinal inflammations, scars and other disorders of choroid	1	28 (3)	17 (1)	46 (1)
Cornea	1 (1)	54 (7)	44 (1)	99 (2)
Disorders of the globe	5 (3)	79 (10)	129 (4)	213 (5)
Optic nerve disorders	11 (8)	40 (5)	49 (1)	100 (2)
Other retinal disorders	4 (3)	18 (2)	36 (1)	58 (1)
Diabetic retinopathy	---	196 (25)	1110 (33)	1306 (31)
Glaucoma	3(2)	66 (8)	354 (11)	423 (10)
Retinal detachments and defects	6 (4)	37 (5)	72 2)	115 (3)
Others	102 (71)	189 (24)	382 (11)	673 (16)
Total—sum of rows	143 (3)	794 (19)	3335 (78)	4272 (100)

CI 14% to 17%), AMD 14% (95% CI 13% to 15%), glaucoma 10% (95% CI 9% to 11%) and disorders of the globe (DG) 5% (95% CI 4% to 6%).

DISCUSSION

This study investigated the prevalence and causes of VI in the Northwest of Portugal. Crude estimates of prevalence point that 2 out of 100 inhabitants of the Portuguese north-western population suffer from VI. Category-specific prevalence by age and by sex revealed higher prevalence among older people and among women. The top causes of VI included DR and cataract, information about causes of VI was available only from cases detected at hospitals.

The prevalence of VI for the sample of the general Portuguese population was within the expected values. Our results are in line with those reported in neighbour countries such as Spain.[43] This was an expected result because both countries have similar demographics and health systems. Our results are also in line with a French study reporting a prevalence of VI of 1.95%.[11] A study from Iceland reported a prevalence of 0.96% (95% CI 0.37% to 1.55%)[1] that is similar to our study if we consider the standardised prevalence instead of the crude prevalence. Another study conducted in 2000 in Copenhagen, urban Denmark, also found a value for prevalence close to 1%.[44] In contrast, a study from 2016 in rural Denmark found a prevalence of 0.4% (95% CI 0.2% to 0.7%),[10] which is similar to what has been reported in Germany 0.37% (95% CI 0.28% to 0.49%).[7] Recent studies show that the incidence of VI in countries like Germany has been reducing and, therefore, more recent studies are likely to report lower prevalence of VI than older studies.[45] One possible explanation for slightly higher values of prevalence of VI in our study in Portugal can be the prevalence and incidence of, for example, diabetes and DR.[46 47] In other words, some European countries seem better at preventing vision loss from common eye diseases such has DR and removing it from top cause of VI. In Portugal at the time of our study DR was still the top cause of VI.[48] In other parts of Europe such as Hungary prevalence of VI was higher than our study, here VI affected more than 5% of the population.[12] In short, the prevalence of VI in Portugal was similar to neighbour countries, but slightly higher than in countries with, possibly, better preventive mechanisms of vision loss. Our results point that is possible to reduce the prevalence of VI in Portugal, the exact strategies can be inspired from European countries reporting lower prevalence of VI.

VI was more common among elderly people, it increased from about 7 out of 10 000 in the population under 25 years to 60 out of 10 000 in the age range 25-64 years and about 300 out of 10 000 in the population with 64 or more years, these findings are in line with other studies.[7] A study in Denmark found that VI was 9 times more prevalent amongst people with more than 64 years than amongst people in the age range 20–64 years.[44] Our results for the older population are also in line with the estimates from a recent meta-analysis estimating the prevalence of VI in people 55 years or older in European countries. The study that included data from Portugal, estimated an overall prevalence of VI for those above 55 years close to 2.75%.[49 50] For age under 25 years, the prevalence of VI in our study was low and in line with several other studies.[51–53] For example, our results were similar to data available from Sweden, in 1997 the age-specific prevalence of VI as 10.9/10 000 among people under the age of 19 years.[53] A more recent study from China that investigated VI amongst preschool children also found a similar prevalence.[54] There was a good agreement between our results and similar studies, small differences might be due, among other factors, to temporal changes in prevalence of VI and the age-range criteria.

The prevalence of VI among females was 1.3 times higher than the prevalence among males, this result is in line with the trend reported in a recent meta-analysis covering European countries.[49] These results are also consistent with studies from Germany,[7] VI among females was 1.4 times higher than among males, and from Spain,[43] prevalence amongst females was 1.7 times higher than amongst males. The female-to-male ratio is expected to vary from 1.1 is sub-Saharan Africa to 1.25 in Europe.[55] Causes for this female-to-male ratio above 1 are likely to include factors such as gender inequalities in access to healthcare.[56]

Table 6 Causes of visual impairment in six European countries, including Portugal

This study	Denmark[45]	Scotland[14]	Italy[59]	Poland[60]	Germany[7]
Diabetic retinopathy	Cataract	Age-related macular degeneration	Cataract	Age-related macular degeneration	Age-related macular degeneration
Cataract	Age-related macular degeneration	Glaucoma	Myopia	Cataract	Glaucoma
Age-related macular degeneration	Diabetic retinopathy	Cataract	Age-related macular degeneration	Amblyopia	Diabetic retinopathy
Glaucoma	Myopic degeneration	Diabetic retinopathy	Diabetic retinopathy	Diabetic retinopathy	Corneal disease
Cornea	Other retinal causes	Myopia	not available	Cornea	Genetic illness

The top two causes of VI in our study were DR and cataract. Information about causes of VI in our study was available from hospitals and that might increase the frequency of cases with treatable diseases such as the top two causes. The main causes of VI in Europe are diverse[57] and we provide a summary of some studies in table 6.[7 14 44 58 59] Studies compiled in table 6 show that, for example, DR was the top cause of VI only in our study. We speculate that the main reason was that when our study was conducted the preventive effects of DR screening were not yet visible in Portugal and, therefore, the number of cases of VI caused by DR was high.[46] This contrasts with other countries such as Germany or Denmark where DR appears down in the list of main causes of VI. Probably here preventive measures were implemented earlier than in Portugal.[46] While in some studies DR remains in second place as cause of VI[60] it seems that the trend is to go further down in the list.[61 62] Our second cause of VI, cataract, has also been reported as important cause of VI in Denmark, Canada and the UK.[10 63 64] We believe that, for example in Denmark, the high number of cases of cataract causing VI was due to the inclusion criteria with acuity 20/40. In many countries, this is also the criteria to undergo cataract surgery. In our study we believe that a considerable percentage of cases of VI caused by cataract was due to long queues for surgery at the time of our study.[65]

In this study we used CR models to investigate prevalence of VI. Some models showed high quality of fit which gives credibility to the prevalence values that we obtained. The best models were the ones with the list dependences primary care centres/hospitals and primary care centres/blind association. Internal validity of the models was assessed using χ^2 goodness of fit tests and AIC. Only the models assuming the list dependence scenario primary care centres/hospitals and primary care centres/blind association passed the χ^2 goodness of fit test. The primary care centres/hospitals dependence is understandable because medical certificates of VI require a report from an ophthalmologist that, most likely, is the assistant physician at the hospital. The primary care centres/blind association dependence is explained by the fact that the blind association recommends their members to get a medical certificate of VI. It was impossible to assess in detail the external validly of our model that computed the hidden population. However, when we compare prevalence of VI for people above 55 years reported by a recent systematic analysis in European countries (prevalence 2.75%)[49] with the estimates in the current study for people with more than 64 years, 3.27% (95% CI 2.36% to 4.90%), it seems like our estimates are accurate. The fact that completeness was about 9% is a limitation of our study, to solve this we needed more information from primary care centres. This limitation may be addressed in future studies with better standardised digital records that allow more efficient anonymous data sharing.

In conclusion, the results of this study showed that prevalence of VI in Portugal was within the expected range and in line with other neighbour countries. A significant number of cases of VI detected was due to preventable causes, in other words, a reduction of cases of VI in Portugal is possible with improved access to eye care and effective diseases monitorisation. In addition, basic and comprehensive vision rehabilitation is necessary to support people with VI.[66] Future studies are necessary to characterise temporal changes and the efficacy of public health measures such as DR screening at reducing prevalence of VI.

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Contributors Contributed equally to this work PLR and AFM. Roles: conceptualisation, data curation, formal analysis, Investigation, methodology, software, validation, visualisation, writing–original draft, writing–review and editing. RS roles: conceptualisation, funding acquisition, methodology, project administration, resources, supervision, validation, writing–review and editing. APM roles: data curation, investigation, validation, visualisation, writing–review and editing. IS roles: methodology, supervision, validation, writing–review and editing. AR-S: conceptualisation, methodology, supervision, validation, writing–review and editing. AFM (guarantor) accepts full responsibility for the finished work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

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