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Changes in incidence and severity of visual impairment due to glaucoma during 40 years – a register-based study in Finland

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ABSTRACT.

Purpose: To report the incidence and severity of reported visual impairment (VI) due to glaucoma and the changes in them during the past 40 years in Finland.

Methods: A register-based study, in which the data were collected from the Finnish Register of Visual Impairment between 1980 and 2019. These data included 5819 visually impaired glaucoma patients, of which 61% were female. Visual impairment (VI) was classified according to the Finnish national definitions. The number of treated glaucoma patients in Finland was calculated using glaucoma medication reimbursement data available between 1986 and 2019 from the Social Insurance Institution of Finland registers.

Results: The incidence of reported VI due to glaucoma per 100 000 persons had increased from 2.3 in the 1980s to 3.4 in the 2010s. During the same time period, the incidence of reported VI per 10 000 treated glaucoma patients had decreased from 32 in the 1980s to 21 in the 2010s. Primary open-angle glaucoma (45%) was the main subtype for reported VI due to glaucoma. During the 40 years, the proportion of mild VI and the age at the onset of reported VI had increased.

Conclusion: The incidence of reported VI due to glaucoma has increased during the 40 years, but the risk of treated glaucoma patients becoming visually impaired has decreased. Visual impairment (VI) also occurs at an older age. This is likely due to the earlier diagnoses and improved therapy. To prevent the unfavourable development of VI due to glaucoma among the ageing population in the future, all attempts need to be made to improve glaucoma care.

Key words: glaucoma – incidence – register-based study – visual impairment

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Introduction

Glaucoma contributes significantly to the global causes of visual impairment (VI) and is the leading cause of irreversible blindness (Tham et al. 2014; Flaxman et al. 2017; GBD 2019 Blindness and Vision Impairment Collaborators & Vision Loss Expert Group of the Global Burden of Disease Study 2021). In Finland, glaucoma is the second most common reason for permanent VI after age-related macular degeneration and before diabetic retinopathy in the population aged 65 years or above (Ojamo 2021). These three prominent causes of VI reflect well with the situation in other Western countries with ageing populations. In Finland, the prevalence of glaucoma is approximately 4% among persons over 50 years and increases with age (Social Insurance Institution of Finland 2021).

Even though glaucoma care has improved during the past decades, glaucoma is still a blinding disease. It is estimated that in the follow-up of 15–20 years, approximately 16% of patients in clinical care will become visually impaired (Forsman et al. 2007; Peters et al. 2013). Since VI causes a severe reduction of quality of life (Taipale et al. 2019) and increases the use and costs of health care services (Mikhailova et al. 2018), it is vital to monitor its incidence and changes not

only to measure the magnitude of this problem but also to evaluate the effectiveness of glaucoma care over time.

The aim of this register-based study was to report the incidence and severity of reported VI due to glaucoma between 1980 and 2019 and the changes in them during 40 years in Finland. We also assessed the age at the onset of reported VI and the age at death in visually impaired glaucoma patients. The data were collected from the Finnish Register of Visual Impairment. Visual impairment (VI) was classified according to the Finnish national definitions (Ojamo 2021). The number of treated glaucoma patients in Finland was obtained from the Social Insurance Institution of Finland registers (2021), based on persons with reimbursement for glaucoma medication.

Materials and Methods

Finnish Register of Visual Impairment and definition of VI

The National Board of Health established the Finnish Register of Visual Impairment in 1983. The operation of the Register is regulated by the Act (556/89) and Decree (774/89) on National Personal Records kept under the Health Care System. The register includes data on eye diagnoses, home region, date of birth, year of onset VI and the classification of VI. The classification of VI is based on the examination of ophthalmologists and the Finnish definitions of VI based on the World Health Organization (1973) definitions with a modification of the nomenclature of the names of the VI classes, which are demonstrated in Table 1: (1) mild vision loss, (2) moderate VI, (3) severe VI, (4) near-total blindness and (5) total blindness. In addition, the sixth class of VI, non-defined blindness, is used when the notification data does not include visual acuity or visual field, but the ophthalmologist has notified the blindness of the person. The time of VI is determined based on the notification data, and if it does not exist, the date of registration is used. By the end of 2019, the register included data on 58 822 visually impaired patients, of whom 18 176 were still alive. In this study, we only included visually impaired

Table 1. Finnish definitions of visual impairment (VI, based on the World Health Organization 1973 definitions with a modification of the nomenclature of the names of the VI classes).

Classification of VI	Visual acuity (VA)	Visual field
Mild vision loss	$0.3 > VA \geq 0.1$	
Moderate visual impairment	$0.1 > VA \geq 0.05$	
Severe visual impairment	$0.05 > VA \geq 0.02$	$\geq 5^\circ$ and $< 10^\circ$ from central fixation
Near total blindness	$0.02 > VA - 1/\infty$	$< 5^\circ$ from central fixation
Total blindness	$VA = 0$, no sense of light	

patients who had glaucoma as the main diagnosis of VI ($n = 5819$).

We acquired the estimated total number of treated glaucoma patients in Finland from the Social Insurance Institution of Finland registers, based on the number of persons with reimbursement for glaucoma medication (data available from 1986 to 2019). Based on this data, we estimated the incidence of reported VI among the treated glaucoma patients. We also calculated the expected number of years with VI using the age at the onset of reported VI and age at death acquired from the Digital and population data

services agency. These figures were compared to the age-specific life expectancies in the general population, provided by Statistics Finland (2021). This study was conducted in line with the tenets of the Helsinki Declaration. As this is a register-based study, the approval of the ethical committee is not needed according to the Finnish legislation.

Statistical analyses

All statistical analyses were performed using R software version 3.5.1 (R Core Team, Foundation for Statistical

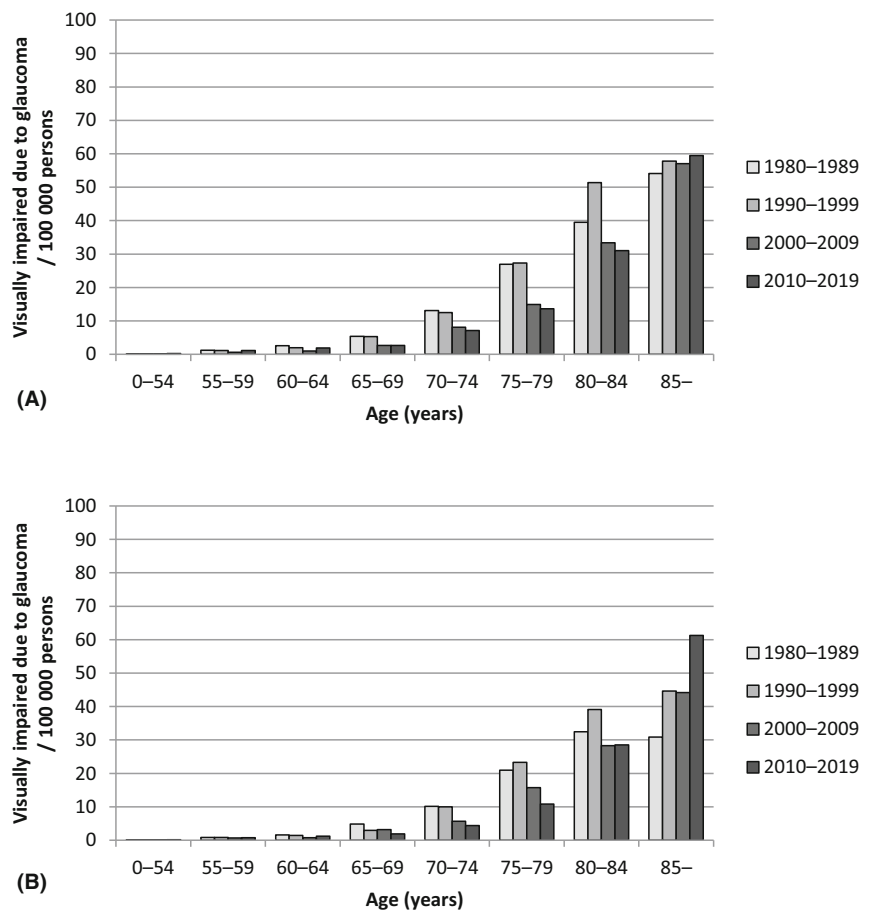


Fig. 1. Incidence of reported visual impairment due to glaucoma per 100 000 Finnish men (A) and women (B) in different decades.

Table 2. Age at the onset of VI in glaucoma patients.

	1980–1989	1990–1999	2000–2009	2010–2019
Men				
<i>n</i>	443	573	513	757
Mean, years (95% CI)	73.9 (72.9–74.9)	75.9 (75.0–76.8)	77.4 (76.4–78.4)	77.5 (76.6–78.4)
Women				
<i>n</i>	661	903	844	1125
Mean, years (95% CI)	76.0 (75.2–76.8)	78.9 (78.3–79.5)	80.7 (80.1–81.3)	82.6 (82.0–83.2)

There was a statistically significant difference in age between sexes in each decade ($p < 0.0001$, Mann–Whitney *U* test).
 CI = confidence interval, VI = visual impairment.

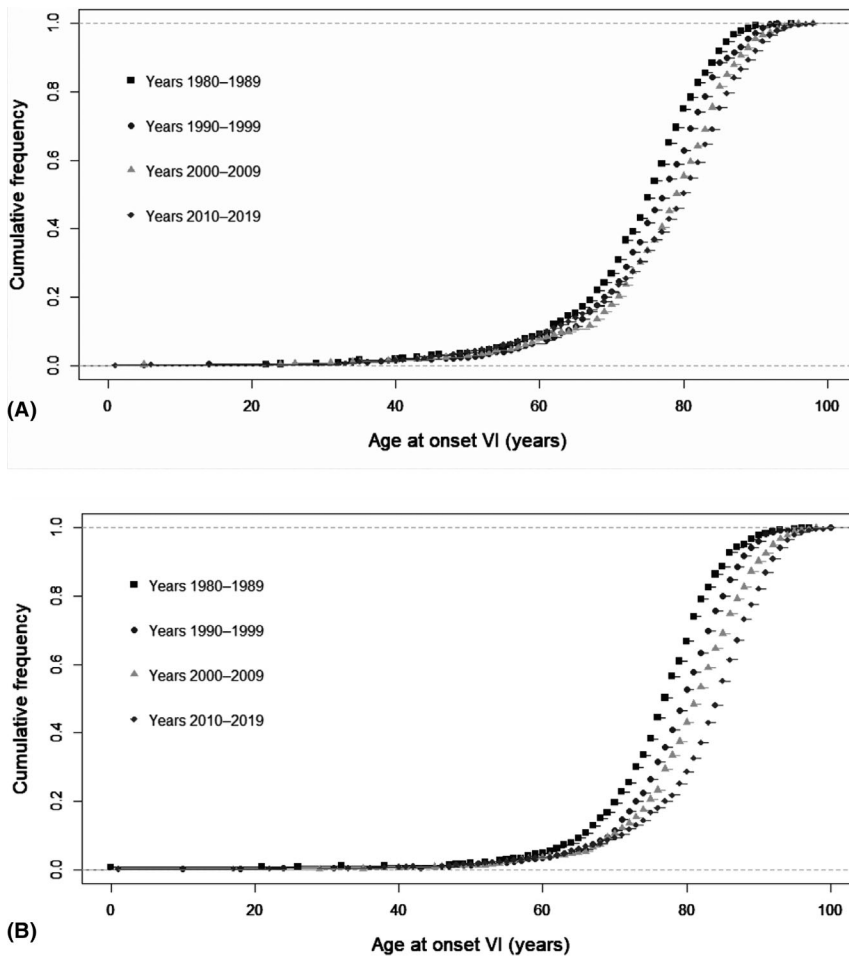


Fig. 2. Cumulative frequency of age at the onset of reported visual impairment (VI) for male (A) and female (B) glaucoma patients in different decades.

Computing, Vienna, Austria). As the distribution of the age data was left-skewed, Mann–Whitney *U* test was used for between-group comparisons and Kruskal–Wallis test to compare multiple groups. A chi-squared test was used for categorical variables when appropriate. A two-tailed *p*-value of < 0.05 was selected to determine statistical significance.

Results

The Finnish Register of Visual Impairment included altogether 5819 visually impaired persons with glaucoma as the main diagnosis, of whom 3533 (61%) were female and 2286 (39%) male. Of these patients, 1104, 1476, 1357 and 1882 had become visually impaired in the 1980s, 1990s, 2000s and 2010s,

respectively. The shares of females were 59.9%, 61.2%, 62.2% and 59.8%, respectively. The calculated incidence of reported VI due to glaucoma in the Finnish population in the four decades by age and sex is shown in Fig. 1. The incidence was higher in women from the 1990s to the 2010s ($p < 0.05$, chi-squared test). The calculated total incidence of reported VI per 100 000 persons were 2.3, 2.9, 2.6 and 3.4 in the four decades, respectively. This increasing trend ($p = 0.0026$) was due to the increase in reported cases in the age group of 85 years and older, especially in women.

The mean age at the onset of reported VI due to glaucoma and the number of glaucoma patients who had become visually impaired in each decade are shown in Table 2 and Fig. S1. The mean age at the onset of reported VI was higher in women compared to men in all decades ($p < 0.0001$, Mann–Whitney *U* test). In addition, the mean age at the onset of reported VI increased with each decade in both sexes ($p < 0.0001$, Kruskal–Wallis test). The mean age at the onset of reported VI had increased by 3.6 years in men and 6.6 years in women between the 1980s and the 2010s. A cumulative age profile of the onset of reported VI in each decade is presented in Fig. 2.

The mean age at death in visually impaired glaucoma patients was investigated in each decade, as shown in Table 3. The mean age at death in women was higher compared to men in all decades ($p < 0.0001$). In addition, the mean age increased with each decade in both sexes ($p < 0.0001$). The development of mean age at the onset of reported VI and age at death between the decades is shown in Fig. 3. The expected number of years with VI had significantly decreased in women from 10.1 years in the 1980s to 7.0 years in the 2010s ($p < 0.0001$, Mann–Whitney *U* test). In men, this decreased from 9.6 years in the 1980s to 8.7 years in the 2010s, but this change was not statistically significant. For both men and women, the number of years with VI did not differ significantly from the life expectancy at the age at the onset of reported VI.

The classifications of reported VI in visually impaired glaucoma patients in the different decades are presented in Fig. 4. The percentage of mild vision

Table 3. Age at death in visually impaired glaucoma patients.

	1980–1989	1990–1999	2000–2009	2010–2019
Men				
<i>n</i>	431	544	443	285
Mean, years (95% CI)	83.5 (82.7–84.3)	84.9 (84.3–85.5)	85.6 (84.9–86.3)	86.2 (85.3–87.1)
Women				
<i>n</i>	647	867	723	442
Mean, years (95% CI)	86.1 (85.6–86.6)	87.7 (87.3–88.1)	88.9 (88.4–89.4)	89.7 (89.1–90.3)

There was a statistically significant difference in age between sexes in each decade ($p < 0.0001$, Mann–Whitney *U* test).
CI, confidence interval.

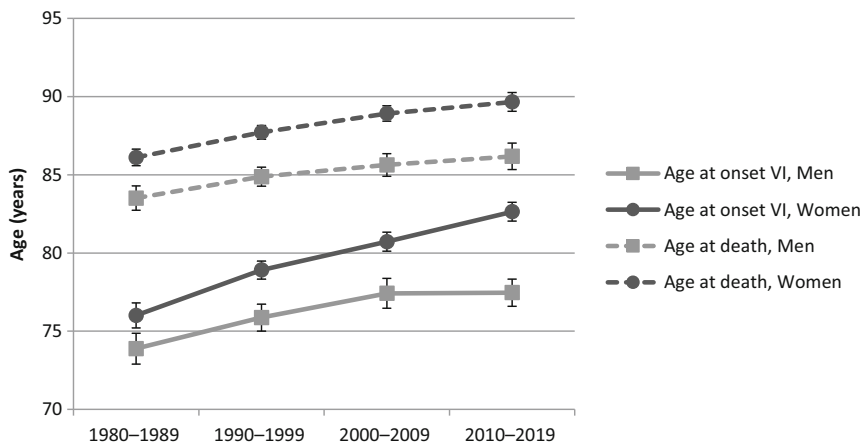


Fig. 3. Age at the onset of reported visual impairment (VI) and age at death (with 95% confidence intervals) in male and female glaucoma patients in different decades.

loss increased from 40% to 51% during the 40 years ($p < 0.0001$). There were no significant differences in the distribution and change of the classifications between sexes.

The percentages of glaucoma subtypes causing VI in Finland are listed in Table 4. During the 40 years, the most common diagnosis has been primary/chronic open-angle glaucoma (44.9%), followed by exfoliative glaucoma (29.8%) and normal-tension glaucoma (7.1%). We also compared this to the data from Puroola et al. (2021a), Health 2000 (Aromaa & Koskinen 2004) and Health 2011 (Koskinen et al. 2012), which demonstrate the proportions of various subtypes of glaucoma in Finland. When compared to Health 2000 data, the risk of VI was highest in exfoliative glaucoma, followed by chronic angle-closure glaucoma, primary/chronic open-angle glaucoma and normal-tension glaucoma ($p < 0.0001$).

The mean numbers of treated glaucoma patients with reimbursed glaucoma medication increased by time: 37 475, 51 339, 69 405, and 88 217 in the four decades, respectively (Fig. S2). At the same time, the share of females declined: 68.8%, 68.9%, 67.1%, and



Fig. 4. Classifications of reported visual impairment in glaucoma patients in different decades.

Table 4. Distribution of glaucoma diagnoses in Finland.

	Glaucoma diagnoses associated with VI 1980–2019 (%)	Glaucoma diagnoses in 2000* (%)	Glaucoma diagnoses in 2011* (%)
Primary/chronic open-angle glaucoma	44.9	39.1	36.6
Exfoliative glaucoma	29.8	20.3	22.5
Normal-tension glaucoma	7.1	5.1	9.7
Pigmentary glaucoma	0.5	3.2	1.2
Unspecified open-angle glaucoma	0.5	1.1	3.0
Acute angle-closure glaucoma	0.2	6.6	3.9
Chronic angle-closure glaucoma	5.1	5.1	3.0
Unspecified primary angle-closure glaucoma	0.2	0.4	0.7
Glaucoma secondary to other disorder/factor	4.7	6.3	7.8
Other glaucoma	7.0	12.8	11.6

* Data from Purola et al. (2021b), Health 2000 (Aromaa & Koskinen 2004), and Health 2011 (Koskinen et al. 2012).

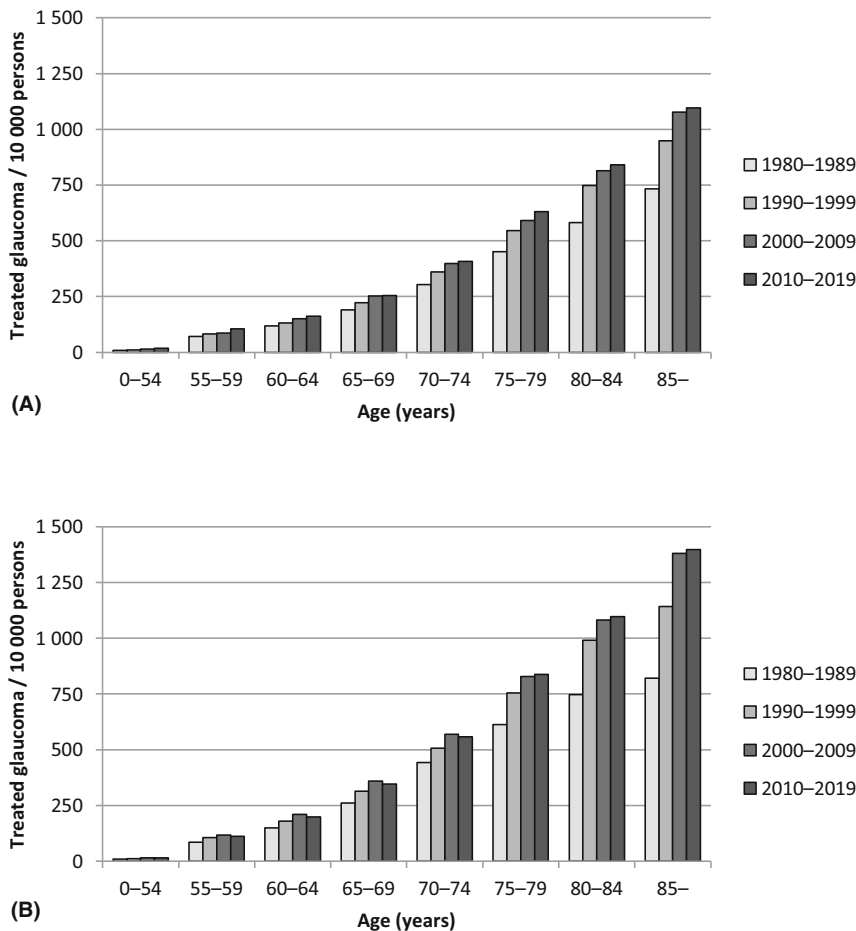


Fig. 5. Prevalence of treated glaucoma per 10 000 Finnish men (A) and women (B) in different decades.

63.3%. The calculated prevalence of treated glaucoma in the Finnish population in the four decades by age and sex is shown in Fig. 5. The prevalence was higher in women from the 1990s to the 2010s ($p < 0.05$). The calculated total prevalence of the treated glaucoma per 10 000 persons was 76, 101, 132 and 161 in the four decades, respectively, showing a significantly increasing trend ($p < 0.0001$). The calculated incidence of reported VI among the treated glaucoma patients is shown in Fig. 6. The calculated total incidence of reported VI per 10 000 treated glaucoma patients was 32, 29, 20 and 21 in the four decades, respectively, showing a significantly decreasing trend ($p < 0.0001$). Although the incidence appeared to be higher in men in all decades, this difference was statistically insignificant (Fig. 6).

Discussion

The number of visually impaired glaucoma patients and the incidence of reported VI due to glaucoma have increased since the 1980s. However, the incidence of reported VI among treated glaucoma patients has decreased in the past four decades in Finland. Similar findings have been presented globally (Flaxman et al. 2017; GBD 2019 Blindness and Vision Impairment Collaborators & Vision Loss Expert Group of the Global Burden of Disease Study 2021). During the same time period, the percentage of mild vision loss among visually impaired glaucoma patients has increased. This positive trend has also been reported globally (Flaxman et al. 2017). These changes suggest that the risk of VI for a glaucoma patient has decreased, probably due to the improved therapeutic options, their availability and earlier diagnosis of glaucoma.

The main subtype of glaucoma causing VI in Finland is primary open-angle glaucoma, followed by exfoliative glaucoma and normal-tension glaucoma. This is in good accordance with the proportions of glaucoma subtypes in Finland (Parkkari et al. 2019; Purola et al. 2021a). As in many other populations of European ancestry (Tham et al. 2014), the prevalence of angle-closure glaucoma and VI due to it is low in Finland (Ojamo 2021). Globally, however, even though open-angle

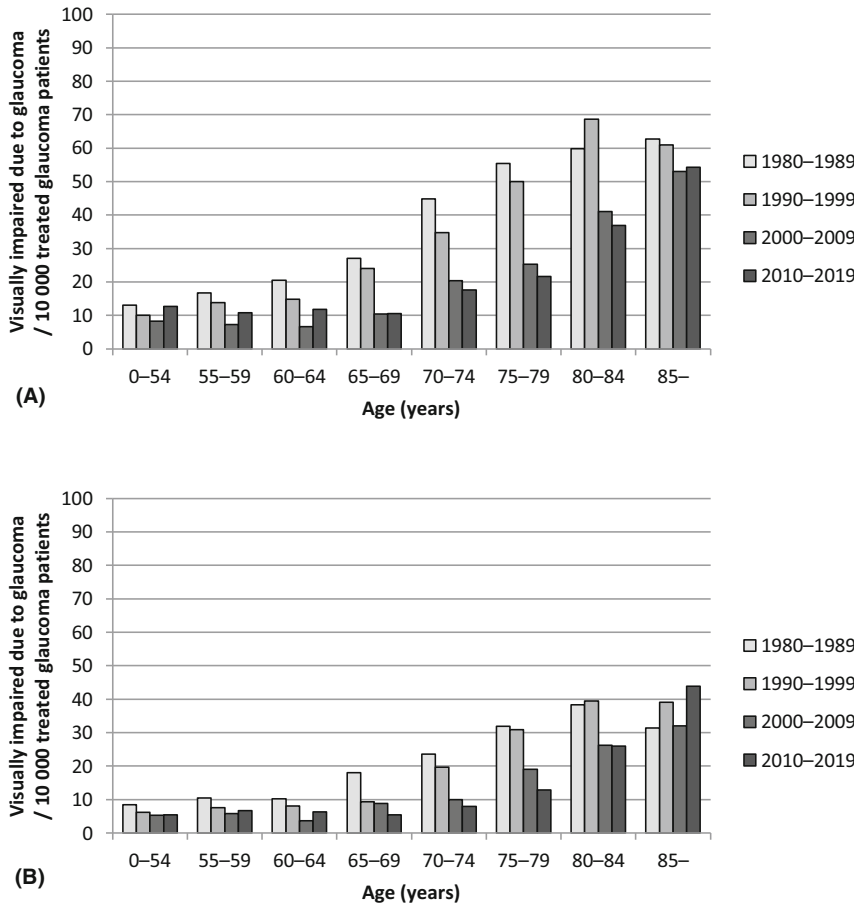


Fig. 6. Incidence of reported visual impairment due to glaucoma per 10 000 Finnish men (A) and women (B) with treated glaucoma in different decades.

glaucoma is substantially more common than angle-closure glaucoma, blindness is more likely to occur in the latter (Quigley & Broman 2006).

The age at the onset of reported VI has increased during the past 40 years. The causes are probably related to better glaucoma care, e.g. improved therapy, their availability and earlier diagnoses. Another explanation could be the increased life expectancy of the population. However, the life expectancy of the glaucoma patients did not significantly differ from that of the general population. Furthermore, the time the glaucoma patients are living visually impaired decreased during the 40 years. This favourable change during the past decades is likely an important factor in the decreasing influence of glaucoma on health-related quality of life (Purola et al. 2021a). This change is also favourable for society because the increased use of health care services and costs are strongly correlated with impaired vision (Köberlein et al. 2013; Mikhailova et al. 2018).

In the Finnish register data, the prevalence and incidence of glaucoma are higher among females (Purola et al. 2021a; Social Insurance Institution of Finland 2021). This is contradictory to many epidemiological findings (Heilj et al. 2013; Flaxman et al. 2017). The reason for this difference is unknown. In our data, the incidence of reported VI is higher among male than female glaucoma patients, which might indicate that the diagnosis of glaucoma and onset of therapeutic measures are happening later in the course of the disease for males. There are indications of gender differences in health behaviour in general (Mahalik et al. 2006; Weber et al. 2019) and in Finland particularly (Koponen et al. 2018), which may explain this difference. In 2019, the life expectancy at birth was still 5.3 years lower for Finnish boys than girls (79.2 versus 84.5 years; Statistics Finland 2021), even though many chronic diseases are more prevalent in women (Koponen et al. 2018).

The prevalence of glaucoma in Nordic countries has been estimated in previous studies. In Reykjavik Eye Study, the prevalence of open-angle glaucoma was 4.0% for those aged 50 years and older (Jonasson et al. 2003). In Sweden, the prevalence of undetected glaucoma was 1.23% (Heilj et al. 2013). There has not been any clear indication on whether the prevalence of glaucoma has changed since the first large population studies were published (Bankes et al. 1968; Kahn et al. 1977). However, the number of treated glaucoma patients has increased during the past 40 years in Finland. This is partly due to the ageing Finnish population (Statistics Finland 2021) and the association of glaucoma with older age (Tielsch et al. 1991; Wolfs et al. 2000; Kapetanakis et al. 2016). Most probably, also the improved awareness of glaucoma and access to health care services during these years explain the trend (Parikka et al. 2018). The increasing number of treated glaucoma patients may also reflect decreasing proportion of undiagnosed glaucoma that has been shown to be high even in Nordic countries with developed public health care (Heilj et al. 2013).

The strengths of our study include the large data based on routinely collected health registers, which ensures that our results are comparable with those from studies in the other Western countries. We had access to data from four decades, giving us a relatively large timescale of 40 years. The notifications of VI due to glaucoma are based on Finnish legislation, and, therefore, the register data covers relatively well the glaucoma cases. The classification of VI is based on the Finnish national definitions and recommendations modified from the World Health Organization 1973 definitions, which cover both decreased visual acuity and visual field constriction.

Our study also has limitations. First, we would like to point out that the prevalence of treated glaucoma does not reflect the prevalence of glaucoma. Therefore, there are several possible biases. As shown previously, there is a large number of undiagnosed even in well-developed countries. Population-based studies in Europe have reported that at least 50% of glaucoma cases remain undiagnosed (Burr et al. 2007;

Topouzis et al. 2008; Heijl et al. 2013). It is also possible that glaucoma diagnoses made for the reimbursement of glaucoma medication can cause misclassification biases. Visual impairment register data, like register data in general, have potential sources of biases, although not as remarkable as those in glaucoma detection. It is difficult to estimate the exact time point at which a person becomes visually impaired, and even more difficult to estimate when the disease itself emerges. In the older population, many of the patients are suffering from more than one vision-threatening disease, such as age-related macular degeneration (Puroola et al. 2021b). Therefore, to minimize this bias, we analysed only those patients whose main diagnosis causing VI was glaucoma. Our data included predominantly people with Finnish backgrounds, and, therefore, the results may not be directly applicable to other countries and ethnicities.

In the conclusion, our study demonstrates that whilst the incidence of reported VI due to glaucoma has increased during the past 40 years, the incidence of reported VI has decreased in the glaucomatous population and shifted to older age groups. Furthermore, the percentage of mild vision loss among the visually impaired has increased from the 1980s to the 2010s. This is likely due to better glaucoma care, e.g. improved therapy, their availability and earlier diagnoses. On the contrary, in the future, the number of glaucoma patients is expected to grow with the ageing population. Therefore, all attempts need to be made to prevent VI by further improving glaucoma care.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Histogram of age at the onset of reported VI for male (A) and female (B) glaucoma patients in different decades in Finland.

Figure S2. Treated glaucoma patients with reimbursed glaucoma medication in Finland between 1986 and 2019. Data were from the registers of the Social Insurance Institution of Finland.