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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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 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

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 ≥ 0.1     |             |
| Moderate visual impairment | 0.1 > VA ≥ 0.05 |             |
| Severe visual impairment | 0.05 > VA ≥ 0.02 | ≥5° and ≤10° from central fixation |
| Near total blindness | 0.02 > VA ≥ 1.00   | <5° from central fixation |
| Total blindness      | VA = 0, no sense of light |           |

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

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

|         | 1980–1989 | 1990–1999 | 2000–2009 | 2010–2019 |
|---------|-----------|-----------|-----------|-----------|
| **Men** |           |           |           |           |
| n       | 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** |           |           |           |           |
| n       | 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.

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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.
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 Purola 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

| Table 3. Age at death in visually impaired glaucoma patients. |
|---------------------------------------------------------------|
|                  | 1980–1989 | 1990–1999 | 2000–2009 | 2010–2019 |
| **Men**          |           |           |           |
| $n$              | 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**        |           |           |           |
| $n$              | 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.

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

**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).

**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
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% (Heijl 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 (Heijl 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;
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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 (Purola et al. 2012). Therefore, to minimize the 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.

References

Aromaa A & Koskinen S (2004): Health and functional capacity in Finland: baseline results of the Finnish 2000 Health Examination Survey (in Finnish). National Public Health Institute, Report 128/2004. Available at: http://urn.fi/URN:NBN:fi-fe201204193452. (Accessed on 15 Feb 2021).

Bankes JLK, Perkins ES, Tsalakis S & Wright JE (1968): Bedford glaucoma survey. Brit Med J 1: 791–796.

Burr J, Mowatt G, Hernández R et al. (2007): The clinical effectiveness and cost-effectiveness of screening for open angle glaucoma: a systematic review and economic evaluation. Health Technol Assess 11: 1–96.

Flaxman SR, Bourne RRA, Resnikoff S et al. (2017): Vision Loss Expert Group of the Global Burden of Disease Study. Global causes of blindness and distance vision impairment 1990–2020: a systematic review and meta-analysis. Lancet Glob Health 5: e1221-e1234.

Forssman E, Kivelä T & Vestå E (2007): Lifetime visual disability in open-angle glaucoma and ocular hypertension. J Glaucoma 16: 309–319.

GBD 2019 Blindness and Vision Impairment Collaborators, & Vision Loss Expert Group of the Global Burden of Disease Study (2021): Causes of blindness and vision impairment in 2020 and trends over 30 years, and prevalence of avoidable blindness in relation to VISION 2020: the Right to Sight: an analysis for the Global Burden of Disease Study. Lancet Glob Health 9: e144-e160.

Heijl A, Bengtsson B & Oskarsdottir SE (2013): Prevalence and severity of undetected manifest glaucoma: results from the early manifest glaucoma screening trial. Ophthalmology 120: 1541–1545.

Jonsson F, Duker JS, Almås A, Sivertsson T, Wang L, Sasaki H & Sasaki K (2003): Prevalence of open-angle glaucoma in Iceland: Reykjavik Eye Study. Eye. 17: 747–753.

Kahn HA, Leibowitz HM, Ganley JP, Kini MM, Colton T, Nickerson RS & Dawber TR (1977): The Framingham Eye Study. I. Outcome and major prevalence findings. Ann J Epidemiol 106: 17–32.

Karapetian KV, Chan MP, Foster PJ, Cook DG, Owen CG & Rudnicka AR (2016): Global variations and trends in the prevalence of primary open angle glaucoma (POAG): a systematic review and meta-analysis. Br J Ophthalmol 100: 86–93.

Körberlein J, Beifus K, Schaffert C & Finger RP (2013): The economic burden of visual impairment and blindness: a systematic review. BMJ Open 3: e003471.

Koponen P, Borodulin K, Lundqvist A, Sääksjärvi K & Koskinen S (2018): Health, functional capacity and welfare in Finland – FinHealth 2017 study (in Finnish). Finnish Institute for Health and Welfare, Report 4/2018. Available at: http://urn.fi/URN:ISBN:978-952-343-105-8. (Accessed on 15 February 2021).

Koskinen S, Lundqvist A & Ristiluoma N (2012): Health, functional capacity and welfare in Finland in 2011 (in Finnish). Finnish Institute for Health and Welfare, Report 6/2012. Available at: http://urn.fi/URN:ISBN:978-952-245-769-1.(Accessed on 15 Feb 2021).

Mahalik JR, Lagan HD & Morrison JA (2006): Health, Behavioural and Masculinity in Kenyan and U.S. Male College Students. Psychol Men Masculin 7: 191–202.

Mikhailova A, Ojamo M, Koskinen S & Uusitalo H (2018): Heikentyneen näkökyynyn tyhjien terveyspalveluiden käyttöön, terveydenhuollon kus-tannuksiin ja elämänlaatuun Suomessa Loppuraportti (in Finnish). The report of Finnish Register of Visual Impairment, Finnish Federation of the Visually Impaired, Finnish Institute for Health and Welfare, and Tampere University. (Accessed on 15 February 2021).

Ojamo M (2021): The Finnish Register of Visual Impairment – annual statistics 2019. Finnish Institute for Health and Welfare and Finnish Federation of the Visually Impaired, Helsinki, Finland. (Accessed on 15 February 2021).

Parikka S, Pentala-Nikulainen O & Koskela T et al. (2018): Kansallisen terveys-, hyvinvointi- ja palvelututkimus FinSoten perustulokset 2017-2018 (in Finnish). Available at: www.tilh.fi/finnote. (Accessed on 15 February 2021).

Parkkari M, Taipale J & Uusitalo H (2019): Changing views on open-angle Glaucoma: definitions and Prevalences – the Rotterdam study. Clin Epidemiol Res 41: 3309–3321.

Parkkari M, Taipale J, Mikhailova A, Ojamo M et al. (2019): Low vision status and declining vision decrease Health-Related Quality of Life: Results from a nationwide 11-year follow-up study. Qual Life Res 28: 3225–3236.

Tham YC, Li X, Wong TY, Quigley HA, Aung T & Cheng CY (2014): Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. Ophthalmology 121: 2081–2090.

The Social Insurance Institution of Finland (2021): Kela statistics. Helsinki. www.kela.fi. (Accessed on 15 February 2021).

Tielch JM, Sommer A, Katz J, Royall R, Quigley H & Javitt J (1991): Racial variations in the prevalence of primary open-angle Glaucoma. JAMA 266: 360.

Topouzis F, Coleman AL, Harris A et al. (2008): Factors associated with undiagnosed open-angle glaucoma: the Thesaloni Eye Study. Am J Ophthalmol 145: 327–335.

Weber AM, Cilaghi B, Mauasone V et al. (2019): Gender Equality, Norms and Health Steering Committees. Gender norms and health from global survey data. Lancet 393: 2455–2468.

Wolfs RC, Borger PH, Ramrattan RS et al. (2000): Changing views on open-angle Glaucoma: definitions and Prevalences – the Rotterdam study. Clin Epidemiol Res 41: 3309–3321.

World Health Organization (1973): The prevention of blindness. TechRep. Ser. 1973, No. 518. Geneva: World Health Organization.

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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.