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DISTRIBUTION OF VERTICAL CUP–DISC RATIO IN A SWEDISH POPULATION

The Tierp Glaucoma Survey

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Date: 2023-08-29

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Populärvetenskaplig sammanfattning

Bakgrund

Glaukom (grön starr) är en neurodegenerativ sjukdom som karakteriseras av kontinuerlig förlust av synnervens axoner(nervfibrer). Följden blir synfältsbortfall och förändringar av synnervsinträdet. Glaukom är en av de främsta orsakerna till permanent synförlust. Fastställandet av C/D–kvoten (eng: cup–disc ratio) har relevans vid glaukomdiagnostik. Värdet bestäms genom att beräkna kvoten mellan exkavationens diameter och synnervspapillens diameter. Vanligtvis beräknas den vertikala diametern. En hög vertikal C/D–kvot innebär större risk att synnervspapillen har en glaukomskada. Flera stora undersökningar har tidigare rapporterat C/D–kvotens fördelning i olika populationer, men inga resultat från svenska studier finns att tillgå. Det primära syftet med denna studie är att redogöra för fördelningen av C/D–kvoten i en svensk normalpopulation. Utöver detta undersöks förhållandet mellan C/D–kvoten och förekomsten av bland annat glaukom och förhöjt ögontryck.

Metod

Materialet som analyserats utgörs av en befolkningsundersökning som utfördes i Tierps kommun mellan 1984–1986. 760 individer i åldern 65–74 år inkluderades i undersökningen. Denna undersöknings primära syfte var uppskatta prevalensen av öppenvinkelglaukom. I och med detta insamlades också skisser av synnervspapillerna. Utifrån dessa skisser bestäms C/D–kvoten manuellt med linjal till en millimeters noggrannhet. Därefter genomfördes olika statistiska analyser för att åskådliggöra resultaten.

Resultat

C/D–kvotens medelvärde var 0.45 i båda ögonen. Det fanns ingen skillnad mellan könen. Distributionen av C/D–kvoterna för hela population var ungefärligen normalfördelad. Ett starkt samband hittades mellan en C/D–kvot i övre kvartilen och öppenvinkel-glaukom (en typ av grön-starr) samt förhöjt ögontryck. Ytterligare påvisades ett samband mellan en ålder på 70 år och äldre och en C/D–kvot i den övre kvartilen.

Slutsatser

Fördelningen av C/D–kvotens i denna studie liknar de resultat som erhållits av tidigare studier med liknande populationer och som använt fotografiska metoder för att avbilda synnervspapillen. En stark korrelation mellan en C/D–kvot i den övre kvartilen och öppenvinkel glaukom samt förhöjt ögontryck hittades. C/D–kvoten ökade också med stigande ålder.

Abstract

Purpose

The aim of this study was to describe the distribution of vertical cup–disc ratio (CDR) in a Swedish population sample. The relationship between cup–disc ratio and intraocular pressure, glaucoma and other factors was also investigated.

Methods

The analysed material was acquired from a population survey conducted in the municipality of Tierp in south central Sweden. Included in the survey were 760 individuals aged 65–74 years. The primary purpose of this study was to estimate the prevalence of open–angle glaucoma. Sketches of the optic disc were obtained as part of the survey. The vertical CDR was determined from these sketches manually by using a ruler, to the accuracy of one millimetre. Odds ratios (ORs), adjusted for age and sex according to Mantel–Haenszel, for a CDR in the upper quartile were calculated using 2 x 2 tables.

Results

The mean vertical cup–disc ratio was 0.45 in both eyes. No difference was observed between the sexes. A strong correlation between a CDR in the upper quartile and open-angle glaucoma (OR 8.06; 95% confidence interval [CI] 4.12–15.8), as well as intraocular pressure $\geq$20 mmHg (OR 2.44; 95% CI 1.64–3.64) were found. An association was also found between age $\geq$70 years and a CDR in the upper quartile (OR 1.62; 95% CI 1.16–2.27). Subjects with a positive family history of open-angle glaucoma had an increased CDR (OR 2.24; 95% CI 1.18–4.24).

Conclusion

The distribution of vertical CDRs in this study was similar to that of other studies on European derived populations using photographic methods. The mean vertical CDR was 0.45 in both eyes. Increased intraocular pressure and open-angle glaucoma were strongly correlated with a CDR in the upper quartile. The CDR also increased with age.

Background

Glaucoma

Glaucoma is a group of ophthalmological diseases which are characterized by damage to the optic nerve and vision loss. Glaucoma is classified as an optic neuropathy. The disease is considered to be present if at least one eye has both the characteristic functional and structural abnormalities i.e., visual field loss and optic disc damage (Quigley, 2011). Globally, glaucoma is the leading cause of irreversible blindness (Tham *et al.*, 2017). The condition is subdivided further into open–angle glaucoma (OAG), angle–closure glaucoma (ACG), secondary glaucoma and congenital glaucoma. OAG is the most frequently occurring form in European derived populations (Jonas *et al.*, 2017). Optic neuropathy is the common feature of all types of glaucoma. It is characterized by a progressive loss of retinal ganglion cells, thinning of the optic disc rim (nerve fibre layer) and cupping of the optic disc (Quigley, 2011). The prevalence in individuals 40 years of age and older is around 3.5% worldwide. In absolute numbers, this resulted in an estimated glaucoma prevalence of 76 million in 2020, with an expected increase to 112 million in 2040 (Jonas *et al.*, 2017). Despite a high prevalence, the condition is frequently undiagnosed. In the industrialised countries, around 50 percent of all OAG are unknown. In the developing countries, however, only 1 in 10 cases are diagnosed (Quigley, 2011).

Several risk factors for the development of glaucoma have been recognised, such as older age, increased intraocular pressure (IOP), ethnicity, family history and myopia (Jonas *et al.*, 2017). The risk for OAG has been found to increase with every decade beyond the age of 40. OAG prevalence is highest in individuals of African ancestry, while ACG is most prevalent in Asian populations. Medical treatment of increased intraocular pressure has been found to slow the progression of visual field loss in OAG (Kass *et al.*, 2002).

Cup–disc ratio

Measuring the vertical cup–disc ratio (CDR) has a long history of use in the assessment of glaucoma patients. This measure is also been suggested to be a part of the classification of glaucoma in population surveys (Foster *et al.*, 2002). CDR is calculated by dividing the optic cup diameter with the optic disc diameter. The development of glaucoma is associated with neuroretinal tissue loss which causes thinning of the optic disc rim and enlargement of the optic cup, which results in a higher CDR (Garway–Heath *et al.*, 1998). The loss of neurons is more rapid in the superior and inferior poles of the optic disc, making vertical CDR the more appealing measurement

(Quigley, 2011).

Optic disc size normally varies considerably between individuals. There is a correlation between the diameter of the optic cup and the size of the disc. On average, larger optic discs have larger cups. One study has shown that the variation in disc size affected clinicians' ability to recognise glaucomatous discs. The sensitivity for recognising glaucoma was lower in smaller discs and higher in larger ones. Specificity, on the other hand, was higher in smaller discs and lower in larger ones. The study concluded that larger discs were more likely to be classified as glaucomatous while smaller discs were more likely to be classified as normal, regardless of whether they were glaucomatous or not (Heijl *et al.*, 2009).

Optic disc imaging

There are several ways of recording the appearance of the optic disc. These methods can generally be divided into two categories. The first involves obtaining digital recordings of the disc, using various imaging technologies. The second involves manually recording the appearance of the disc, as observed during some form of biomicroscopic examination of the eye. The format of the manual recording can vary and may range from a written description in the patient record, to the use of a systematic diagramming technique (Shaffer *et al.*, 1975). Included in the first category are methods such as optic disc photography, confocal scanning laser ophthalmoscopy (CSLO) and optical coherence tomography (OCT) (Yuksel Elgin *et al.*, 2022).

Optic disc photography is the most widely used, as well as oldest method in the first category. It enabled objective documentation of the appearance of the disc and allowed for longitudinal comparison. The main disadvantage of traditional photography is the observer dependent assessment of the image. CSLO and OCT, however, are examples of more modern methods which allow for an objective structural evaluation of the optic disc. Currently, OCT is the most advanced technology available for quantifying structural damage of the optic nerve in glaucoma diagnostics (Yuksel Elgin *et al.*, 2022).

Methods described in the second category have generally been used when advanced imaging technologies have been unavailable. One such method, devised as a substitute to photography, uses two circles divided by squares of the size of 0.2 disc diameters (Shaffer *et al.*, 1975). A drawing of a glaucomatous disc using this method can be seen in **Figure 1**.

Figure 1.
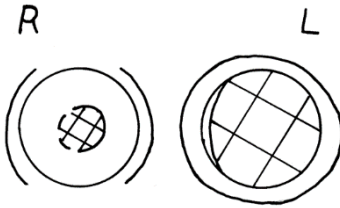
Drawing of the optic discs in a patient with open–angle glaucoma in the left eye.

R = right eye; L = left eye.

Previous studies on cup–disc ratio

The distribution of vertical CDR in different populations has been reported previously by numerous studies. In the Beaver Dam Eye Study, the median vertical CDR was determined to be 0.36, while the mode was 0.3. Other studies found the mode to be higher. The mode of the vertical CDR reported in the Blue Mountains– and Reykjavik Eye Studies were 0.4 and 0.5, respectively (Klein *et al.*, 1992; Mitchell *et al.*, 1996; Jonasson *et al.*, 2003). An overview of the distribution of vertical CDR from these earlier studies is presented in **Table 1**.

One study, performed in central Iran, found the mean vertical CDR and the standard deviation (SD) to be 0.32 (SD 0.14) in non–glaucomatous individuals (Pakravan *et al.*, 2013). Another study, conducted in southern India, reported normal values of 0.43 (SD 0.17) in an urban population, and 0.39 (SD 0.17) in a rural population (Vijaya *et al.*, 2008). As far as we are aware, no data on CDR has previously been reported in a Swedish context.

Table 1. Distribution of vertical cup–disc ratio in right eyes in four population studies.

Study	Method	Mode	Median	Mean
Beaver Dam [1]	Photography	0.3	0.36	–
Blue Mountains [2]	Photography	0.4	–	0.43
Melbourne [3]	Slit lamp examination	0.3	–	0.38
Reykjavik [4]	Photography	0.5	–	–

Method = Method used to assess the cup–disc ratio.

[1] Klein BEK et al. 1992.

[2] Mitchell et al. 1996.

[3] Wensor MD et al. 1998.

[4] Jonasson F et al. 2003.

Aims

The aim of this project is to describe the distribution of vertical cup–disc ratio in individuals examined in the Tierp Glaucoma Survey. The relationship between cup–disc ratio, intraocular pressure, and glaucoma, among other variables, will also be investigated.
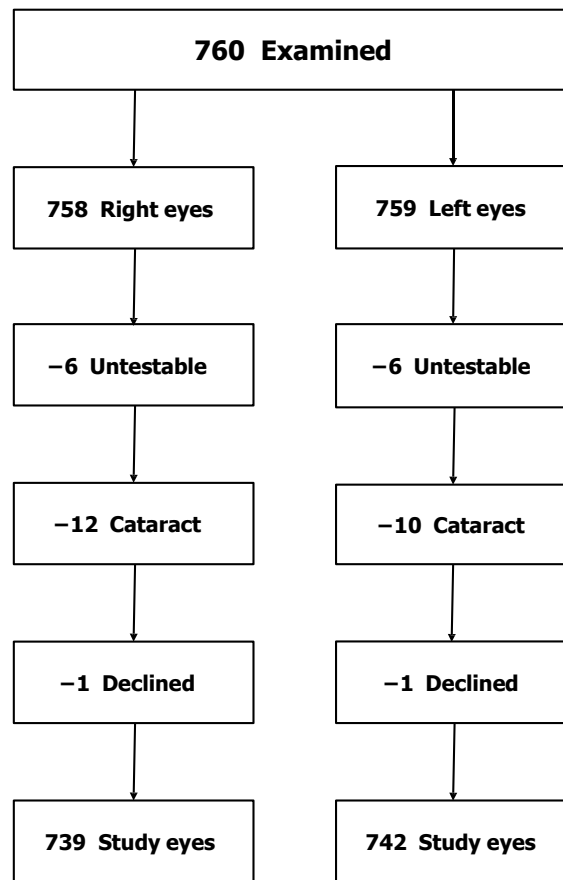
Material and Methods

Population

The target population was inhabitants, aged 65–74, in the municipality of Tierp, central Sweden. At the beginning of the study, Tierp had 2,377 inhabitants in the age group 65–74 (Official Statistics of Sweden 1984). Due to practical considerations, the extent of the study was limited to approximately one third of the target population. The selection was done by obtaining two lists of eligible residents whose date of birth was divisible by the number 3. The lists were provided by the Department of Social Medicine, University of Uppsala. One of the lists contained subjects born between 1910 and 1914, while the second list included subjects born between 1916 and 1920. The basis for these two lists was the population register, and they included personal identity numbers, names, and addresses. Letters were sent out inviting eligible residents to participate in the study. In all, the study involved 838 individuals, of whom 760 (90,7%) were examined.

Of the total number of 760 participants, the right eye had been removed in two subjects and the left eye in one subject, leaving 758 right and 759 left eyes for analyses. Six people were impossible to examine, as were the optic disc of 12 right and 10 left eyes with pronounced cataract. The eyes of these subjects were excluded from the analyses of the respective eye. One subject declined the instillation of eye drops (**Figure 2**). The remaining 739 right eyes and 742 left eyes were used for the analyses of cup–disc ratios.

For the analyses of predictors of an increased cup–disc ratio, the eye with the most advanced OAG, or with the highest pressure, designated 'the eye under study', was chosen. One patient with angle–closure glaucoma and two patients with secondary glaucoma in either eye were removed from this part of the study, as was one individual with dense cataract in both eyes. As mentioned above, six people were impossible to examine, and one declined. Thus, 749 individuals provided information for this part of the study.

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                    │      760  Examined      │
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          ┌──────────────────┐    ┌──────────────────┐
          │  758  Right eyes  │    │  759  Left eyes   │
          └──────────────────┘    └──────────────────┘
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          ┌──────────────────┐    ┌──────────────────┐
          │  −6  Untestable   │    │  −6  Untestable   │
          └──────────────────┘    └──────────────────┘
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          ┌──────────────────┐    ┌──────────────────┐
          │  −12  Cataract    │    │  −10  Cataract    │
          └──────────────────┘    └──────────────────┘
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          ┌──────────────────┐    ┌──────────────────┐
          │   −1  Declined    │    │   −1  Declined    │
          └──────────────────┘    └──────────────────┘
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          ┌──────────────────┐    ┌──────────────────┐
          │  739  Study eyes  │    │  742  Study eyes  │
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Figure 2. Flow chart showing how the study samples of 739 right eyes and 742 left eyes in the Tierp Glaucoma Survey were derived.

Definitions

In this study, a visual field defect, consistent with glaucoma, and not otherwise explainable, was required for the diagnosis of definite OAG. Chronic simple glaucoma and capsular glaucoma were classified as OAG. To obtain a diagnosis of pseudoexfoliation, the edge of the pupil and the anterior part of the lens were observed. Cataract was diagnosed when lens opacities were observed with the pupil dilated at least 3 mm. Those who had a history of cataract surgery were also classified as having cataract. A participant was classified as having diabetes mellitus if at least one of these three conditions was met; 1) Ongoing treatment for diabetes mellitus; 2) Diagnosis of diabetes mellitus in the medical record; 3) Diagnosis of diabetes mellitus acquired within two years of the screening examination. A participant was classified as having treatment for hypertension or ischaemic heart

disease in the case of a positive history or if a diagnosis was present in the medical records. Information about smoking was acquired from participants, medical records, or family members.

Screening Procedure

The 760 participants of the study were examined at the Eye Clinic in Tierp. To begin with, participants were interviewed regarding their medical and family history. Intraocular pressure was obtained by a Goldmann applanation tonometer mounted on a Haag–Streit slit lamp. Visual fields were examined with the Competer 350 automated perimeter (Bara Elektronik AB, Lund, Sweden). After dilation of the pupils, slit lamp examination was performed, including binocular assessment of the optic discs and gonioscopy.

Sketches of the optic discs were made in the protocol using a modified version of the method recommended by Schaffer et al. (1975). The diameter of the cup was marked as the point on the disc surface, where its definite transition posteriorly began. The inner margin of the scleral ring was defined as the disc margin. The optic discs were classified in the following categories: 1) non–glaucomatous discs; 2) glaucomatous discs, not excavated to the disc margin; 3) glaucomatous discs, excavated to the disc margin at any part of the circumference. During the examination of the optic discs, the ophthalmologist was masked from the results of the visual field test and the intraocular pressure measurements. Lastly, haemorrhages and other abnormalities were noted.

Measuring the cup–disc ratio

The CDR was calculated by dividing the optic cup diameter by the optic disc diameter. The dimension of the optic disc in the protocol was 15.5mm. The optic cup diameter was obtained by measuring the greatest extent of the excavation between 45–135° and 225–315°. These measurements were made in a joint session, using a ruler to the accuracy of 1 mm. The vertical CDR was then calculated by dividing the optic cup diameter by 15.5.

Statistics

The distribution of the vertical CDR is presented in a table and a figure. Odds ratios for cup–disc ratios in the upper quartile in the eye under study were calculated using 2 x 2 tables. Mantel–Haenszel adjusted odds ratios were used to control for age and sex. A logistic regression model was used to evaluate multiple potential predictors of a high cup disc–ratio in the eye under study, with a

cup–disc ratio in the upper quartile as the dependent variable. The agreement between repeated measurements of the CDR was evaluated using Cohen's kappa coefficient. Thus, the readings of the CDR of the first 100 individuals in the sample were repeated and kappa coefficients calculated for both eyes.

Ethical Considerations

The investigation was approved by the Human Subjects Committee at the Faculty of Medicine, Uppsala University, and adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all participants.

Results

Participation

The Tierp Glaucoma Survey involved 838 individuals. 760 (90.7%) of whom were examined. Participation in the survey, categorised by age and sex, is displayed in **Table 2**. The participation rate for both males and females was higher in the age group 65–69 years compared to 70–74 years. The highest rate was seen in females aged 65–69 years and the lowest in men aged 70–74. Of the 760 examined individuals, 749 provided information for this study, as explained previously.

Distribution of vertical cup–disc ratio

The distribution of vertical CDR in the eye under study is presented in **Figure 3**. The measurements were approximately normally distributed. The distribution of mean CDRs in right and left eyes, by age and sex is presented in **Table 3**. The mean CDR was 0.43 for right eyes and 0.42 for left eyes in the age group 65–69 years. In the age group 70–74 years, the mean CDR was 0.47 in right and 0.48 in left eyes. In total, the mean was 0.45 in both eyes. Thus, the mean CDR was higher in the older age group. The median was 0.45 in both eyes, with a ratio of 0.52 defining the upper quartile. No differences between the sexes were observed.

Table 2. Participation in the Tierp Glaucoma Survey by age and sex.

	Females (*n* = 429)				Males (*n* = 409)			
	Examined				Examined			
Age	Yes	(%)	No	(%)	Yes	(%)	No	(%)
65−69 years	209	(93.3)	15	(6.7)	195	(90.7)	20	(9.3)
70−74 years	187	(91.2)	18	(8.8)	169	(87.1)	25	(12.9)
65−74 years	396	(92.3)	33	(7.7)	364	(89.0)	45	(11.0)
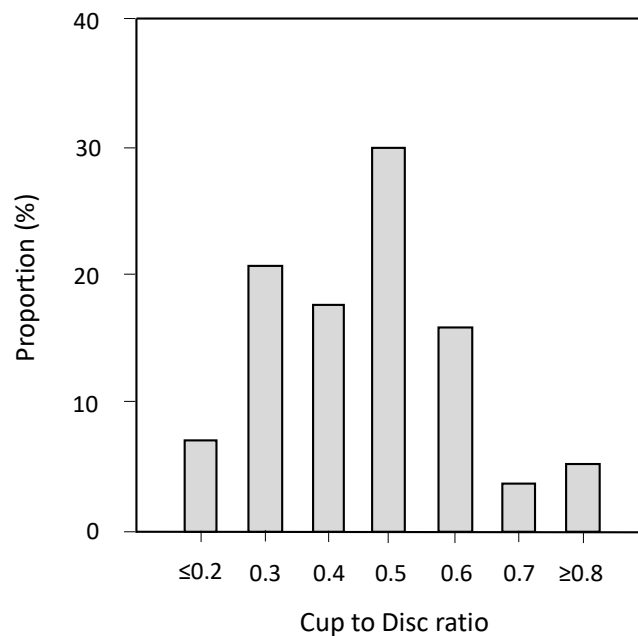
Figure 3. Distribution of vertical cup to disc ratio in 749 eyes in the Tierp Glaucoma Survey. The eye with the most advanced open–angle glaucoma, or the highest intraocular pressure, was chosen. The optic disc in both eyes of 11 people were not examined.

Table 3. Distribution of mean vertical cup–disc ratios in right and left eyes in the Tierp Glaucoma Survey by age and sex.

Age	Females		Males		All	
	Right	Left	Right	Left	Right	Left
	(n = 382)	(n = 385)	(n = 357)	(n = 357)	(n = 739)	(n = 742)
65–69 years	0.42	0.42	0.43	0.43	0.43	0.42
70–74 years	0.48	0.47	0.47	0.48	0.47	0.48
65–74 years	0.45	0.44	0.45	0.46	0.45	0.45

Kappa coefficients

Kappa coefficients were calculated based on two separate readings of the first 100 right and first 100 left eyes. For a CDR ≥ 0.5, the coefficients were 0.98 and 0.93 for the right and left eye, respectively.

Predictors of high cup–disc ratio

Odds ratios, adjusted for age and sex according to Mantel–Haenszel, for CDRs in the upper quartile are presented in **Table 4**. Increased risks were obtained for age ≥70 years (OR 1.62), family history of OAG (OR 2.24), IOP ≥20 mmHg (OR 2.44) and OAG (OR 8.06). No significant effects were observed for sex, pseudoexfoliation, cataract, smoking, diabetes, hypertension, or ischaemic heart disease.

In the logistic regression models, a CDR in the upper quartile was used as the dependent variable. The predictors used were age ≥70 years, family history of OAG, intraocular pressure 20–24 and ≥25 mmHg, as well as ischaemic heart disease. The results are presented in **Table 5** and are consistent with the results of the stratified model.

Table 4. Odds ratios for cup–disc ratios in the upper quartile in the eye under study in the Tierp Glaucoma Survey, adjusted for age and sex.

Characteristics		No. of cases (*n* = 185)	OR $_{MH}$ (95% CI)	
Age ≥70 years [1]	No	82	1.00	
	Yes	103	1.62	(1.16–2.27)
Male sex [2]	No	95	1.00	
	Yes	90	1.03	(0.74–1.44)
Family history, open–angle glaucoma [2]	No	168	1.00	
	Yes	17	2.24	(1.18–4.24)
Intraocular pressure ≥20 mmHg	No	132	1.00	
	Yes	53	2.44	(1.64–3.64)
Open–angle glaucoma	No	155	1.00	
	Yes	30	8.06	(4.12–15.8)
Pseudoexfoliation, either eye	No	156	1.00	
	Yes	29	1.21	(0.76–1.93)
Cataract	No	134	1.00	
	Yes	51	1.24	(0.84–1.84)
Smoking status	Never smoked	125	1.00	
	Past smoker	41	1.17	(0.74–1.87)
	Current smoker	19	0.55	(0.32–0.95)
Diabetes mellitus	No	159	1.00	
	Yes	26	1.20	(0.74–1.97)
Hypertension, treated	No	137	1.00	
	Yes	48	0.86	(0.59–1.26)
Ischaemic heart disease	No	148	1.00	
	Yes	37	1.54	(0.99–2.38)

CI = confidence interval; OR $_{MH}$ = Mantel–Haenszel adjusted odds ratio.
The eye under study includes the eye with the most advanced open–angle glaucoma or the highest pressure.
[1] Adjusted for sex; [2] adjusted for age.

Table 5. Logistic regression model assessing the influence of potential predictors of cup–disc ratios in the upper quartile in the eye under study in the Tierp Glaucoma Survey.

Covariate	No. of cases (n = 185)	OR	(95% CI)
Age, years			
65–70	82	1.00	
70–74	103	1.70	(1.20–2.39)
Family history of OAG			
No	168	1.00	
Yes	17	1.95	(1.00–3.81)
Intraocular pressure, mmHg			
<20	132	1.00	
20–24	39	2.06	(1.32–3.23)
≥25	14	3.99	(1.77–9.00)
Ischemic heart disease			
No	148	1.00	
Yes	37	1.52	(0.97–2.38)

CI = confidence interval; OAG = open–angle glaucoma; OR = odds ratio.

The eye under study includes the eye with the most advanced OAG or the

highest pressure.

Discussion

Participation

The participation rate of this study was 90.7%. The sample were aged between 65–74 years and of white European origin. Ideally, comparisons of the results ought to be made with studies on a similar population. The age-span is narrower than in many other studies. This needs to be taken into consideration when making comparisons with other studies.

Kappa statistics

The kappa coefficients obtained for a CDR $\geq$ 0.5, were 0.98 and 0.93 for the right and left eye, respectively. These kappa values indicate an excellent agreement between repeated measurements of the CDR (McHugh, 2012).

Distribution of vertical cup–disc ratio

The mean vertical CDR for both left and right eyes was 0.45 in this study. This result is similar to the result of the Blue Mountains Eye Study, which reported a mean CDR of 0.43 (Mitchell *et al.*, 1996). The mean CDR of participants in the present study was higher than observed in the Framingham Eye Study, which reported a mean CDR of 0.25 (Leibowitz *et al.*, 1980). A comparison of the percentage distribution of mean vertical CDR between the present study and the Framingham study is presented in **Table 6**.

Methodological differences could account for the conflicting results obtained in these two studies. The Framingham study used indirect ophthalmoscopy to visualise the disc while a binocular examination was made in the present study. It could be argued that a stereoscopic visualisation of the disc facilitates a more accurate assessment of the cup margin, and consequently a more accurate determination of the CDR. The Melbourne Eye Study, using slit lamp examination to visualise the disc, estimated the mean CDR to 0.38 (Wensor *et al.*, 1998). That result is closer to the ratio of 0.45 found in the present study. It is likely that the similarity between the methods accounts for the similarity between the results.

Table 6. Percent distribution of vertical cup–disc ratios for eyes screened in people aged 65–74 years in the Framingham Eye Study and the Tierp Glaucoma Survey.

Study	No.	<0.3	0.3	0.4	0.5	0.6	0.7	≥0.8	Mean
				Cup–disc ratio					
Framingham [1]	1628	53.7	24.4	11.7	4.3	3.4	1.4	1.1	0.25
Tierp [2]	1481	7.2	21.8	17.5	29.6	15.9	3.4	4.5	0.45

[1] Leibowitz et al. 1980; [2] Ekström C 1996.

Overall, the distribution of CDRs in the present study were fairly similar to that of other studies on European derived populations using photographic methods (Klein *et al.*, 1992; Mitchell *et al.*, 1996; Jonasson *et al.*, 2003).

In accordance with most of the population studies referred to in this report, the distribution of vertical CDRs approximately followed a normal distribution. Nevertheless, there was an evident dip in the graph of CDRs with a ratio of 0.4 (**Figure 3**). Unfortunately, we have no plausible explanation for this finding.

Predictors of high cup–disc ratio

In this study increased intraocular pressure and OAG were strongly related to a CDR in the upper quartile. Similar findings have been reported in previous studies (Pakravan *et al.*, 2013). The risk for a CDR in the upper quartile increased progressively, with increasing intraocular pressure. Considering the well-known relationship between increased intraocular pressure and the risk for developing OAG (Ekström, 2012), this finding was not surprising.

A smaller, but still significant result was that an age ≥70 years was associated with a CDR in the upper quartile. One earlier study has reported an increase in the average mean vertical CDR of around 0.1 between the ages of 30 and 70 years (Garway-Heath *et al.*, 1997). Although the age-span in that study was much larger than that of this study, it might indicate a tendency for the CDR to increase with age. Another study found that the effect of increased intraocular pressure on the

cupping of the optic disc increased with age (Klein *et al.*, 2006). It is possible that this effect also plays a role in the result of the current study. Furthermore, subjects aged ≥70 years were examined approximately one year earlier than those aged <70 years. It cannot be ruled out that the judgement of the optic discs had changed while the study was in progress, and thereby introduced an observational bias.

A positive family history of OAG was associated with a two-fold increased risk for having an increased CDR, both in the stratified and the multivariate analyses. The recognised relationship between a positive family history and OAG (Jonas *et al.*, 2017) is a likely explanation for this finding.

Strengths and weaknesses

The study design was a clear advantage of this study. The cross-sectional approach and randomised selection process in conjunction with a high participation rate gives reliability to the representativeness of the results for the included ages. Similar findings were obtained from both the logistic regression models and the stratified analyses which lends credibility to the results. Another methodological strength was the high kappa coefficients, which indicated that the method used for measuring the CDR from the sketches was reliable.

One obvious disadvantage was that more advanced techniques have been developed for morphological and structural analysis of the optic disc than those used in this study. The use of such methods could have provided more detailed and nuanced results than those obtained in the current study. Other weaknesses of the study were the limited size of the population sample and a narrow age-span. The size of the sample could account for the lack of statistical significance in terms of tendencies found between different variables and a CDR in the upper quartile. Another potential weakness was that the examinations and optic disc sketches were performed by a single ophthalmologist. If an observational bias was present, it would likely have affected the results in some way. On the other hand, the fact that the examinations were performed by a single individual could also be interpreted positively, as it eliminates the possibility of inter-observer variation.

Conclusions

The mean vertical CDR of subjects aged 65–74 years in this cross-sectional population study conducted in Sweden was 0.45. This result is close to earlier studies on European derived populations perfomed using a similar methodology. Increased intraocular pressure and OAG were strongly correlated with a CDR in the upper quartile. The CDR also increased with age.

Acknowledgements

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