

# Pseudophakia and Lens Opacities in 70-Year-Olds in Gothenburg, Sweden; Gender Differences, Impact on Self-Reported Visual Function and Validation of Self-Reported Cataract and Pseudophakia

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**Purpose:** The study aimed at determining the prevalence and sex differences in cataract, pseudophakia, lens opacities and self-reported cataract in 70-year-old people in Gothenburg, Sweden. The purpose was also to identify correlations between lens opacities, visual acuity and subjective visual function, and to validate self-reported cataract and cataract surgery.

**Patients and Methods:** Population-based cross-sectional study where participants (n=1182) answered questions about self-reported diagnosis of cataract and cataract surgery. A total of 1139 subjects completed the National Eye Institute Visual Functioning Questionnaire-25 (NEI VFQ-25), 560 subjects underwent ophthalmic examination including visual acuity and lens photography. *t*-test, Pearson chi-square and Mann-Whitney *U*-test were used for obtaining p-values. ANOVA (analysis of variances, Kruskal-Wallis, one-way) was used to compare VFQ-25 between 3 groups; no cataract, cataract and pseudophakia. To clarify the differences between specific pairs of groups post-hoc test (Bonferroni) was used after ANOVA.

**Results:** Self-reported cataract was more common in women than in men (27.2% vs 19.1%,  $p=0.001$ , chi-square). Cataract surgery was reported by 16.3% of women and 12.6% of men ( $p=0.072$ ). Upon eye examination, the prevalence of pseudophakia was 16.9% in women compared to 10.2% in men ( $p=0.020$ ). The prevalence of cataract, including pseudophakia, was 31.9% in women versus 23.8% in men ( $p=0.033$ ). Significant correlations (Spearman's rho) were found between lens opacities and visual acuity. Self-reported cataract surgery showed a very high specificity and high sensitivity. The composite score from NEI VFQ-25 was lower in people with pseudophakia than in people with/without cataract ( $p=0.012$ , Kruskal-Wallis).

**Conclusion:** The prevalence of cataract including pseudophakia in 70-year-olds in Gothenburg is higher compared to previous studies in similar geographical areas. Also, it is more common in women than in men. The lack of significant sex differences in lens opacities may be due to cataract surgery at an earlier stage. Validation showed very good agreement between pseudophakia and self-reported cataract surgery.

**Keywords:** cataract, cataract surgery, cross-sectional study, gender differences, lens opacities, vision-related quality of life

## Introduction

Globally, cataract is the major cause of blindness. Out of the 36 million who are blind worldwide, 35% is caused by cataract.<sup>1</sup> In Sweden, the annual number of cataract extractions have steadily increased from 2014 until 2019, when the

number of cataract surgeries were 139,665 according to the Swedish National Cataract register.<sup>2</sup> In 2020, the number of cataract extractions decreased to 121 310, most likely due to the Covid-19 pandemic.<sup>3</sup> For many years now, cataract extraction has been the most common surgical procedure in Sweden. More women than men have cataract surgery, but the proportion of women going through cataract extractions have gradually decreased since 2000, and the percentage in 2020 was 56%.<sup>3</sup> Mean age at the time of surgery has decreased since 1999, resulting in a mean age of 73 years in 2020, and visual acuity at the time of surgery has gradually increased.

Epidemiological studies in ophthalmology are important for future planning of health care, for the comparison of disease burden and number of cataract extractions over time, as well as for further investigations of risk factors for the development of cataract. Updated information will provide increased knowledge within health care and society, for care recipients and care providers. Local studies are valuable because the prevalence may vary due to different risk factors in different populations thus affecting the prevalence of cataract and cataract surgery. Studies from several countries, including Sweden, have shown that the prevalence of lens opacities is higher in women than in men.<sup>4–7</sup> Our study aimed to investigate if this is still the case, and to relate the results to the decreasing proportion of women undergoing cataract extractions, and to explore if there is inequality in access to health care.

The objective of this study was to determine updated sex-specific prevalence of cataract based on assessment of pseudophakia and lens opacities in 70-year-old people in the Gothenburg area in Sweden and relate these results to self-reported cataract. The study also aimed at exploring correlations between lens opacities, visual acuity and self-reported visual function using the National Eye Institute Visual Function Questionnaire (NEI VFQ-25) and the Rasch-based scoring algorithm National Eye Institute Visual Functioning Questionnaire 28 (NEI-VFQ-28R). Furthermore, the study aimed at investigating if there is conformity between self-reported cataract or pseudophakia, and diagnosis of cataract or pseudophakia as evaluated through examination, which is relevant for future studies exploring self-reported cataract and self-reported cataract surgery.

## Materials and Methods

### Participants

The Gothenburg H70 Birth Cohort Study is a population-based cross-sectional study, which started in 1971, investigating normal and pathological aging in older populations.<sup>8</sup> In the Gothenburg H70 Birth Cohort Study of 2014–2016, 70-year-olds born in 1944 on specific dates (dates ending with 0, 2, 5 or 8) were selected from the Swedish Population Register.<sup>9</sup> Inclusion criteria were living in the urban area of Gothenburg and being able to communicate in Swedish. A total of 1182 individuals (633 women, 549 men) answered questions on cataract surgery, cataract diagnosed by an ophthalmologist or optician, age-related macular degeneration or diabetic eye disease diagnosed by an ophthalmologist, previous laser surgery for diabetic eye disease and present or previous treatment for glaucoma. A total of 1139 individuals (614 women, 525 men) completed the National Eye Institute Visual Function Questionnaire (NEI VFQ-25).<sup>9,10</sup>

From the cohort of 1203, a subsample of 631 participants, born on days ending with 0, 2, 5 and 8 (born in January–April), and 5 and 8 (born in May–December), were invited for an ophthalmic examination conducted at Sahlgrenska University Hospital, Mölndal. Of those invited, 560 completed the ophthalmological examination; 295 were women (52.7%), and 265 were men (47.3%). Further details on the recruitment of participants can be found in a study by Havstam Johansson et al.<sup>9</sup> The ophthalmological examination was conducted in 2014–2015 by specially trained ophthalmologic nurses and included, among other things, best corrected visual acuity (BCVA) using the Early Treatment Diabetic Retinopathy Study Chart (ETDRS),<sup>11</sup> lens and fundus photographs taken after pupil dilatation with eyedrops containing cyclopentolate 0.85% and phenylephrine 1.5%. Lens photographs were slit-lamp images for grading nuclear color and nuclear opacities, and retroillumination images for grading cortical cataract and posterior subcapsular cataract. The fundus photograph comprised the posterior pole.

### Ethics Approval and Consent to Participate

The study was approved by the Regional Ethical Review Board (Dnr 869–13, 127–14). The study was performed in accordance with the tenets of the Declaration of Helsinki and written informed consent was obtained from all participants. All participants gave consent for publication of data.

## Procedure

Lens opacities were graded in the right eye, independently from the lens photographs by two ophthalmologists, using Lens Opacities Classification System (LOCS) III, which is an established and wide-spread method for grading lens opacities. LOCS II was updated to LOCS III in 1993<sup>12</sup> and consists of six slit-lamp images for grading nuclear color (NC) and nuclear opalescence (NO) and five retroillumination images for grading cortical cataract (CC) and posterior subcapsular cataract (PSC). NO and NC were graded from 0.1–6.9 with 0.1-unit intervals and CC and PSC were graded from 0.1–5.9 with 0.1-unit intervals. One resident in ophthalmology and one professor of ophthalmology assessed the LOCS grading independently. In cases where the difference in grading was more than one unit, the resident re-assessed the cases, and an average was calculated. Not all photographs could be assessed regarding lens opacities because of the quality of the photographs; 0.7–1.1% of the photographs depending on type of lens opacity. If data was missing according to either of the observers the other observer's data was used.

In the Skövde Cataract study,<sup>6</sup> which was implemented in a geographical area close to the Gothenburg area, the definition of cataract was converted from a definition according to LOCS II in the Eye Diseases Prevalence Research group<sup>13</sup> into LOCS III, and the definition of cataract was one or more of the following in either eye: PSC>1, CC>3 and/or NO≥4. This definition was also used in the present study. In some analyses, pseudophakia was included in the definition of cataract. To determine interrater reliability, the degree of agreement among raters, Cohen's  $\kappa$  was calculated. Sensitivity, specificity, positive predictive values and negative predictive values of self-reported cataract and self-reported cataract surgery were calculated by comparing the questions "Have you ever been diagnosed with cataract by an ophthalmologist or optician?" and "Have you ever had cataract surgery?" with cataract and pseudophakia as diagnosed from the lens photographs. Smoking was defined as self-reported ever smoker, diabetes as self-reported type 1 or type 2.

NEI VFQ-25 has been widely used in ophthalmological research and consists of 25 questions which are grouped into 12 subscales: general vision, ocular pain, near vision, distance vision, social functioning, role limitations, dependency, mental health, driving, peripheral vision, color vision and a single general health question. Its purpose is to assess influence of visual impairment on health-related quality of life.<sup>14</sup> Each subscale is scored from 0–100 where 0 represent the worst possible and 100 is the best possible self-reported vision-targeted quality of life.<sup>15</sup>

Rasch measurement theory analysis has been used for transformation of questionnaire data to a continuous scale, thus enabling parametric statistical analysis. Rasch analyses of VFQ-25 have resulted in the Rasch-based scoring algorithm for the National Eye Institute Visual Functioning Questionnaire 28 (NEI-VFQ-28-R). In NEI-VFQ-28-R, the items are grouped into two broad domains; Activity Limitations (AL) with 19 items where 7 are additional, and Socio-Emotional Functioning (SEF) with 9 items, and a total score. 1139 participants answered VFQ-25 and the answers were converted into a Rasch-based score, according to the manual by Petrillo.<sup>16</sup> The additional questions were not used. VFQ-25 and NEI-VFQ-28-R scores were assessed for participants with no cataract, cataract and pseudophakia based on findings from the eye examination. The group with no cataract included bilaterally phakic people with no significant lens opacities. The group with cataract included people with lens opacities in either eye according to the definition of cataract. The pseudophakic group included people with pseudophakia in both eyes or pseudophakia in one eye but no significant lens opacities in the fellow eye. If pseudophakia in one eye and significant lens opacities in the other eye the participant was included in the cataract group. If data was missing in one eye, the lens status of the other eye was used.

## Statistics

A power-analysis was performed based on gender differences in self-reported cataract. Using an effect size of 10% between genders, an  $\alpha$ -error probability of 5% and a power (1- $\beta$ -error) of 80%, a desired total sample size of 622 subjects was obtained. Thus, the actual total sample size of 1182 participants was judged as sufficient. *t*-test, Pearson Chi-square and Mann–Whitney *U*-test were used for obtaining *p*-values. Results from LOCS gradings and vision-related quality of life are presented as median with interquartile range (IQR) and mean with standard deviation (SD). Cohen's  $\kappa$  was calculated in order to determine interrater reliability. According to Landis and Koch,  $\kappa$ -values of 0.41–0.60 constitute moderate agreement and 0.61–0.80 is referred to as substantial agreement.<sup>17</sup> Logistic regression, using a backwards stepwise approach, was used for analyzing the impact of sex, diabetes and smoking, on cataract and cataract extraction.

ANOVA (Analysis of Variances) (Kruskal–Wallis, One-way) was used comparing VFQ-25 and Rasch analysis between 3 groups; no cataract, cataract and pseudophakia. To clarify the differences between specific pairs of groups, the post-hoc test Bonferroni was used after the ANOVA-test. All statistical analysis were performed using version 25.0 of IBM SPSS Statistics for Macintosh (IBM Corp, Armonk, NY, USA) except for power-analysis for which the free-to use software G\*power (Heinrich Heine Universität Düsseldorf, Version 3.1.9.6) was used. P-values of <0.05 were considered statistically significant.

## Results

The prevalence of self-reported cataract as diagnosed by an ophthalmologist or optician was 23.4%; 27.2% in women compared to 19.1% in men ( $p=0.001$ , chi-square), see Table 1. The prevalence of self-reported cataract surgery was 14.6%; 16.3% in women versus 12.6% in men ( $p=0.072$ ). When excluding participants stating cataract surgery from participants stating cataract diagnosis, the number decreased to 9.0%; 11.1% in women compared to 6.6% in men ( $p=0.007$ ). All, except one, who stated having had cataract surgery also stated having cataract diagnosed by an ophthalmologist or optician.

Out of the 560 examined subjects, 13.8% were pseudophakic in at least one eye; 16.9% of the women vs 10.2% of the men,  $p=0.020$ , see Table 2. Among women, 31.9% had cataract including pseudophakia in at least one eye, compared to 23.8% in men ( $p=0.033$ , chi-square). The prevalence of cataract, excluding pseudophakia, was 14.9% in women and 13.6% in men.

The odds-ratio for women compared to men for pseudophakia was 1.91 (95% confidence interval [CI] 1.15–3.16;  $p=0.012$ ). The odds-ratio for women having cataract in either eye (including pseudophakia) was 1.46 (95% CI 1.00–2.12;  $p=0.051$ ).

**Table 1** Prevalence of Self-Reported Diagnosis of Cataract and Previous Cataract Surgery | 182 70-Year Old People in Sweden Answered Questions About Cataract Diagnosis and Previous Cataract Surgery

Lens Status	Women n=633	Men n=549	p-value	Total N=1182
Self-reported cataract, n (%)	172 (27.2)	105 (19.1)	0.001 <sup>a</sup>	277 (23.4)
Self-reported previous cataract surgery, n (%)	103 <sup>b</sup> (16.3)	69 (12.6)	0.072 <sup>a</sup>	172 (14.6)
Self-reported cataract excluding self-reported previous cataract surgery, n (%)	70 (11.1)	36 (6.6)	0.007 <sup>a</sup>	106 (9.0)

Notes: A p-value < 0.05 was considered significant, <sup>a</sup>Pearson Chi-square, <sup>b</sup>One women reporting cataract surgery does not report cataract.

**Table 2** Pseudophakia and Lens Opacities in Swedish 70-Year Olds; Gender Differences

Parameter	Women	Men	p-value	Total
Lens status	n=295	n=265		N=560
- Phakic both eyes, n (%)	245 (83.1)	238 (89.8)	0.020 <sup>a</sup>	483 (86.3)
- Pseudophakic one eye, n (%)	14 (4.7)	11 (4.2)	0.734 <sup>a</sup>	25 (4.5)
- Pseudophakic two eyes, n (%)	36 (12.2)	16 (6.0)	0.012 <sup>a</sup>	52 (9.3)
- Pseudophakic in at least one eye, n (%)	50 (16.9)	27 (10.2)	0.020 <sup>a</sup>	77 (13.8)
Nuclear opalescence <sup>b</sup>	n=253	n=238		N=491
- Mean (SD)	2.26 (0.65)	2.19 (0.69)	0.265 <sup>c</sup>	2.22 (0.67)
- Median (IQR)	2.20 (1.80–2.70)	2.15 (1.60–2.65)	0.280 <sup>d</sup>	2.20 (1.75–2.65)
Nuclear color <sup>b</sup>	n=253	n=238		N=491
- Mean (SD)	2.02 (0.71)	1.92 (0.67)	0.133 <sup>c</sup>	1.97 (0.69)
- Median (IQR)	2.10 (1.53–2.45)	2.03 (1.34–2.36)	0.211 <sup>d</sup>	2.05 (1.40–2.40)

(Continued)

**Table 2** (Continued).

Parameter	Women	Men	p-value	Total
Cortical cataract <sup>b</sup>	n=254	n=235		N=489
- Mean (SD)	1.18 (0.98)	1.17 (0.95)	0.888 <sup>c</sup>	1.17 (0.96)
- Median (IQR)	0.85 (0.55–1.71)	0.85 (0.45–1.85)	0.804 <sup>d</sup>	0.85 (0.53–1.80)
Posterior subcapsular cataract <sup>b</sup>	n=254	n=236		N=490
- Mean (SD)	0.25 (0.39)	0.25 (0.43)	0.864 <sup>c</sup>	0.25 (0.41)
- Median (IQR)	0.10 (0.10–0.15)	0.1 (0.1–0.1)	0.488 <sup>d</sup>	0.10 (0.10–0.15)
Cataract in either eye, n (%)	44 (14.9)	36 (13.6)	0.545 <sup>a</sup>	80 (14.3)
Cataract in either eye (including pseudophakia), n (%)	94 (31.9)	63 (23.8)	0.033 <sup>a</sup>	157 (28.0)

**Notes:** A p-value < 0.05 was considered significant, <sup>a</sup>Pearson Chi-square, <sup>b</sup>Assessed in the right eye, according to LOCS III, by two observers independently, <sup>c</sup>t-test, <sup>d</sup>Mann-Whitney U-test.

**Abbreviations:** IQR, interquartile range; SD, standard deviation.

Logistic regression showed that even after adjustment for smoking and diabetes, female gender was still a significant risk factor for cataract and cataract surgery, see [Table 3](#).

Grading lens opacities in the right eye showed that the mean of NO was 2.22 (SD 0.67), NC 1.97 (0.69), CC 1.17 (0.96) and PSC 0.25 (0.41). There were no significant sex differences in type of lens opacities. Grading of lens opacities had an inter-rater reliability ( $\kappa$  value) of 0.60 for NO  $\geq 2$ , 0.62 for NC  $\geq 2$ , 0.56 for CC  $\geq 2$  and 0.64 for PSC  $\geq 1$ .

When comparing self-reported cataract surgery with lens photographs, self-reported cataract surgery had a sensitivity of 90.7% (95% CI 82.0–95.4%), a specificity of 99.2% (95% CI 97.9–99.7%), a positive predictive value (PPV) of 0.944 (95% CI 0.866–0.978) and a negative predictive value (NPV) of 0.986 (95% CI 0.970–0.993). Self-reported cataract, as diagnosed by an ophthalmologist or optician, had a sensitivity of 52.9% (95% CI 45.1–60.7%), a specificity of 92.3% (95% CI 89.2–94.5%), a PPV of 0.730 (95% CI 0.641–0.804) and an NPV of 0.832 (95% CI 0.794–0.865). The prevalence of self-reported cataract and cataract surgery in the group who had eye examination was approximate to the prevalence in the whole group; 20.9% versus 23.4% and 13.0% versus 14.6%.

Best-corrected visual acuity (BCVA) was lower in participants with cataract, defined as lens opacities according to the definition of cataract, than without cataract. In the right eye, median ETDRS score was 83.00 letters (IQR 79.00–87.50) compared to 87.00 letters (83.00–90.00) ( $p < 0.001$  Mann-Whitney U-test), see [Table 4](#).

The pseudophakic group had significantly lower self-reported vision-related quality of life according to VFQ-25 and NEI-VFQ-28-R compared to the groups without cataract (bilateral phakia and no cataract), or with lens opacities defined as cataract, in the following subscales: general health, general vision, ocular pain, distance vision, composite overall score, Rasch activity limitations, Rasch total, see [Table 5](#).

Post-hoc test (Bonferroni) showed that the differences in general health ( $p = 0.013$ ), general vision ( $p = 0.035$ ), distance activities ( $p = 0.046$ ), ocular pain ( $p = 0.055$ ) and composite overall score ( $p = 0.084$ ) were between the groups with no cataract and pseudophakia. When the participants with self-reported other eye disease were excluded the significant differences between the groups with different lens status disappeared, see [Supplemental Table 1](#). 19.5% of people with

**Table 3** Logistic Regression of Possible Predictors for Cataract and Cataract Surgery in 70-Year Old People

Covariates for Cataract and Cataract Surgery	B	SE	OR	95% CI	p-value
Diabetes type 1 and type 2	0.706	0.301	2.025	1.12–3.65	0.019
Female gender	0.428	0.195	1.534	1.05–2.25	0.029
Ever smoker	0.113	0.196	1.120	0.76–1.65	0.564

**Notes:** Binary logistic regression. N = 539 (participants), A p-value of <0.05 was considered statistically significant.

**Abbreviations:** B, regression coefficient; CI, confidence interval; OR, adjusted odds ratio; SE, standard error.

**Table 4** Best Corrected Visual Acuity (BCVA) in Participants with and without Cataract

Lens Status	With Cataract	Without Cataract	p-value
BCVA - ETDRS score right eye, n=487 - Median (IQR)	n=57 83.00 (79.00–87.50)	n=430 87.00 (83.00–90.00)	<0.001 <sup>a</sup>
BCVA - ETDRS score left eye, n=480 - Median (IQR)	n=59 85.00 (81.00–88.00)	n=422 87.00 (83.00–90.00)	
BCVA - decimal right eye, n=487 - Median (IQR)	n=57 1.00 (0.80–1.00)	n=430 1.00 (0.80–1.25)	0.003 <sup>a</sup>
BCVA - decimal left eye, n=480 - Median (IQR)	n=59 1.00 (0.80–1.25)	n=422 1.00 (1.00–1.25)	

**Notes:** A p-value < 0.05 was considered significant, <sup>a</sup>Mann–Whitney U-test.

**Abbreviations:** ETDRS, Early Treatment Diabetic Retinopathy Study; IQR, interquartile range; SD, standard deviation.

**Table 5** Visual-Related Quality of Life Using National Eye Institute Visual Functioning Questionnaire (VFQ-25) and a Rasch-Based Scoring Algorithm for the National Eye Institute Visual Functioning Questionnaire (NEI-VFQ-28-R)

Subscale	Cataract	No Cataract	Pseudophakic	p-value
<b>General health</b>	n=85	n=386	n=63	
Median (IQR)	50.00 (50.00–75.00)	75.00 (50.00–75.00)	50.00 (50.00–75.00)	0.021 <sup>a</sup>
Mean (SD)	57.94 (23.21)	61.14 (23.40)	51.98 (25.12)	0.014 <sup>b</sup>
<b>General vision</b>	n=84	n=386	n=63	
Median (IQR)	80.00 (80.00–80.00)	80.00 (80.00–80.00)	80.00 (60.00–80.00)	0.056 <sup>a</sup>
Mean (SD)	78.33 (13.25)	79.90 (14.20)	74.92 (17.22)	0.036 <sup>b</sup>
<b>Ocular pain</b>	n=85	n=386	n=62	
Median (IQR)	100.00 (87.50–100.00)	100.00 (87.50–100.00)	100.00 (75.00–100.00)	0.048 <sup>a</sup>
Mean (SD)	90.44 (13.73)	92.33 (13.83)	87.70 (17.46)	0.047 <sup>b</sup>
<b>Near vision</b>	n=85	n=386	n=63	
Median (IQR)	91.67 (75.00–100.00)	91.67 (83.33–100.00)	83.33 (75.00–100.00)	0.147 <sup>a</sup>
Mean (SD)	86.08 (14.85)	88.32 (14.41)	85.58 (14.53)	0.212 <sup>b</sup>
<b>Distance vision</b>	n=85	n=386	n=63	
Median (IQR)	91.67 (83.33–100.00)	100.00 (83.33–100.00)	91.67 (75.00–100.00)	0.021 <sup>a</sup>
Mean (SD)	95.74 (8.53)	91.31 (12.60)	87.04 (13.86)	0.031 <sup>b</sup>
<b>Social function</b>	n=85	n=386	n=63	
Median (IQR)	100.00 (100.00–100.00)	100.00 (100.00–100.00)	100.00 (87.50–100.00)	0.542 <sup>a</sup>
Mean (SD)	95.74 (8.53)	95.50 (9.23)	93.25 (12.86)	0.238 <sup>b</sup>
<b>Mental health</b>	n=85	n=386	n=62	
Median (IQR)	93.75 (87.50–100.00)	93.75 (87.50–100.00)	93.75 (87.50–93.75)	0.069 <sup>a</sup>
Mean (SD)	91.18 (9.21)	92.18 (9.79)	90.12 (9.97)	0.249 <sup>b</sup>
<b>Role difficulties</b>	n=85	n=386	n=62	
Median (IQR)	100.00 (87.50–100.00)	100.00 (87.50–100.00)	100.00 (75.00–100.00)	0.621 <sup>a</sup>
Mean (SD)	91.47 (14.07)	91.84 (13.98)	89.52 (16.04)	0.492 <sup>b</sup>
<b>Dependency</b>	n=85	n=386	n=62	
Median (IQR)	100.00 (100.00–100.00)	100.00 (100.00–100.00)	100.00 (100.00–100.00)	0.923 <sup>a</sup>
Mean (SD)	98.73 (5.06)	98.68 (6.12)	98.52 (5.34)	0.976 <sup>b</sup>
<b>Driving</b>	n=70	n=308	n=44	
Median (IQR)	87.50 (75.00–100.00)	87.50 (75.00–100.00)	87.50 (75.00–100.00)	0.388 <sup>a</sup>
Mean (SD)	85.18 (17.46)	87.01 (14.85)	82.96 (19.46)	0.231 <sup>b</sup>
<b>Color vision</b>	n=85	n=386	n=63	
Median (IQR)	100.00 (100.00–100.00)	100.00 (100.00–100.00)	100.00 (100.00–100.00)	0.965 <sup>a</sup>
Mean (SD)	97.35 (8.65)	97.02 (9.75)	96.43 (11.76)	0.851 <sup>b</sup>

(Continued)

Table 5 (Continued).

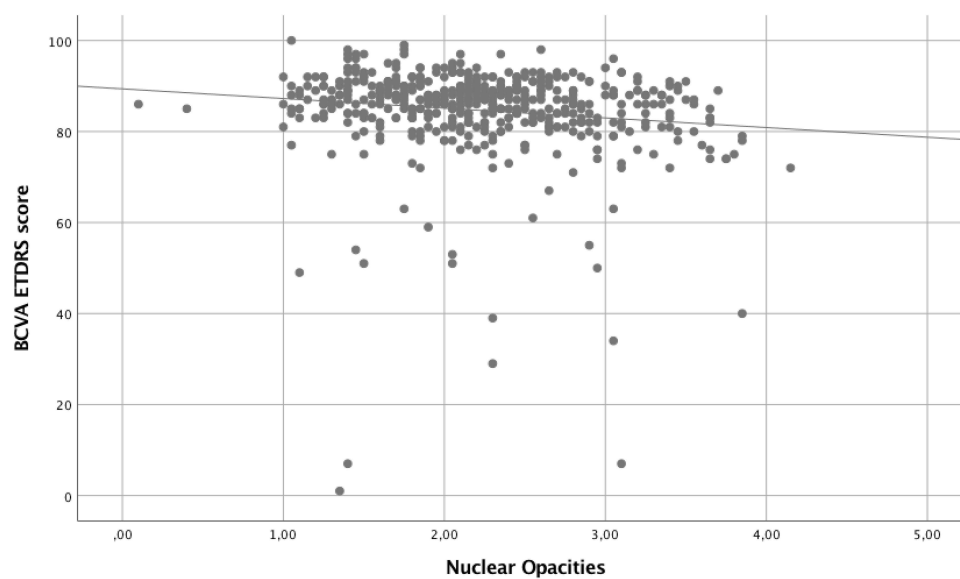
Subscale	Cataract	No Cataract	Pseudophakic	p-value
<b>Peripheral vision</b>	n=85	n=386	n=63	
Median (IQR)	100.00 (75.00–100.00)	100.00 (75.00–100.00)	100.00 (75.00–100.00)	0.632 <sup>a</sup>
Mean (SD)	87.94 (19.14)	89.78 (16.48)	88.89 (15.41)	0.644 <sup>b</sup>
<b>Composite overall score</b>	n=85	n=386	n=62	
Median (IQR)	92.31 (87.66–96.48)	93.87 (87.82–96.99)	90.89 (85.35–94.82)	0.012 <sup>a</sup>
Mean (SD)	90.21 (8.37)	91.31 (8.48)	88.75 (8.66)	0.068 <sup>b</sup>
<b>Rasch activity limitations</b>	n=85	n=386	n=63	
Median (IQR)	56.00 (53.00–58.00)	57.00 (54.00–58.00)	55.00 (53.00–58.00)	0.017 <sup>a</sup>
Mean (SD)	55.15 (3.30)	55.68 (3.44)	54.68 (3.54)	0.066 <sup>b</sup>
<b>Rasch socio-emotional domain</b>	n=85	n=386	n=63	
Median (IQR)	100.00 (90.00–100.00)	100.00 (90.00–100.00)	100.00 (83.33–100.00)	0.363 <sup>a</sup>
Mean (SD)	94.06 (9.78)	94.72 (9.80)	92.40 (12.00)	0.228 <sup>b</sup>
<b>Rasch total</b>	n=85	n=386	n=63	
Median (IQR)	62.00 (59.00–63.00)	62.00 (60.00–63.00)	61.00 (59.00–63.00)	0.045 <sup>a</sup>
Mean (SD)	60.58 (3.11)	60.93 (3.28)	60.03 (3.40)	0.108 <sup>b</sup>

Notes: A p-value <0.05 was considered significant. <sup>a</sup>Kruskal–Wallis 1-way ANOVA, <sup>b</sup>One-way ANOVA.

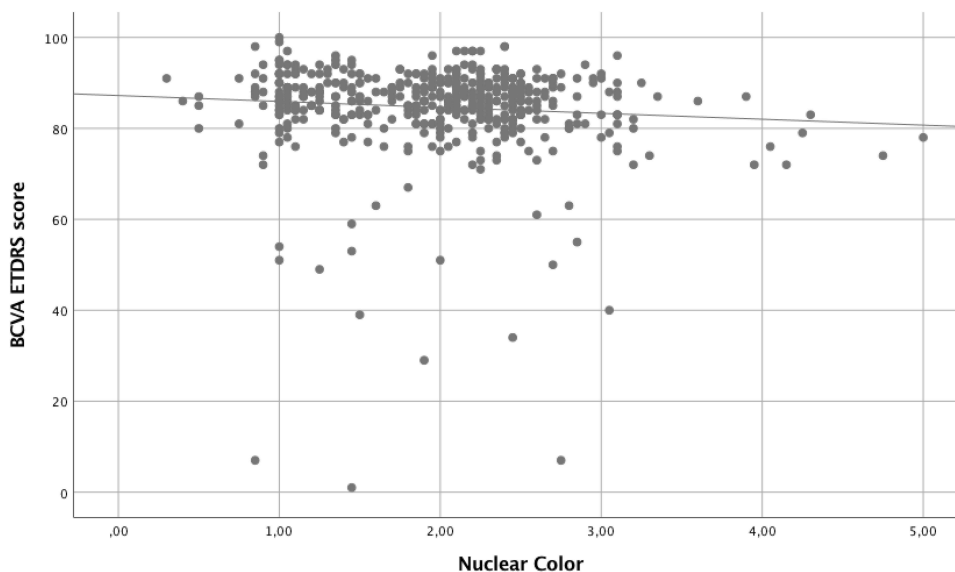
Abbreviations: IQR, interquartile range; SD, standard deviation.

pseudophakia had self-reported other eye-diseases compared to 8.8% ( $p=0.053$ , chi-square) of people with cataract, and 6.2% ( $p<0.001$ ) in people without cataract or pseudophakia.

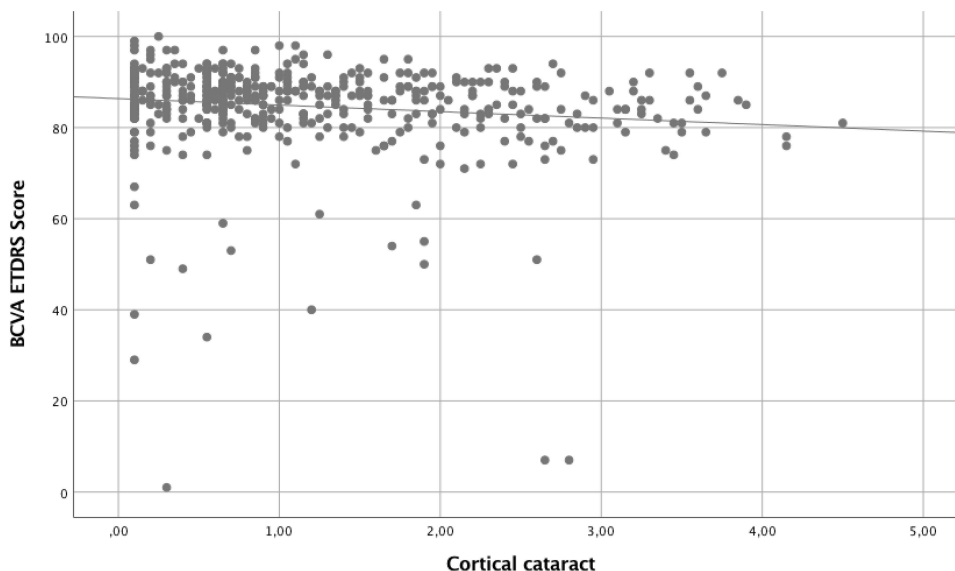
There were significant correlations (Spearman's rho) between visual acuity and NO, NC, CC and PSC (Figures 1–4), where higher lens gradings were correlated with lower visual acuity. For men, there was a significant correlation between NO, NC and PSC and BCVA but for women there was only a significant correlation between CC and BCVA.



**Figure 1** Correlation between visual acuity and nuclear opacities in right eye. 560 70-year-olds in Gothenburg went through an eye examination including lens photographs and BCVA (best corrected visual acuity) measured according to ETDRS (Early Treatment Diabetic Retinopathy Study). The lens photographs were assessed by 2 ophthalmologists according to LOCS III (Lens Opacities Classification System III) and gradings were made for nuclear opacities, nuclear color, cortical cataract and posterior subcapsular cataract. Spearman's rho:  $-0.215$ ,  $p<0.001$ . Spearman's rho: Men  $-0.297$  ( $p=0.000$ ). Spearman's rho: Women:  $-0.116$  ( $p=0.067$ ).



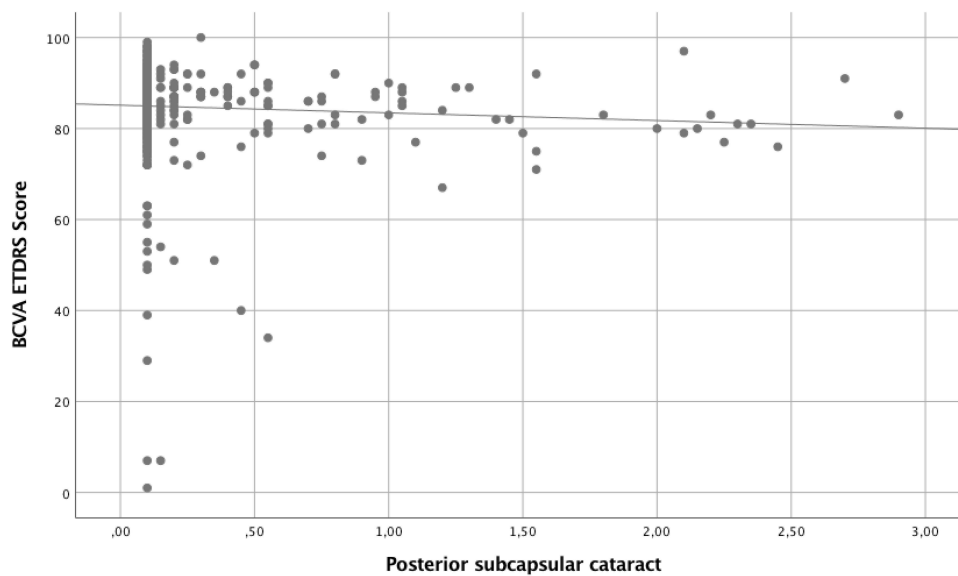
**Figure 2** Correlation between visual acuity and nuclear color in right eye. 560 70-year-olds in Gothenburg went through an eye examination including lens photographs and BCVA (best corrected visual acuity) measured according to ETDRS (Early Treatment Diabetic Retinopathy Study). The lens photographs were assessed by 2 ophthalmologists according to LOCS III (Lens Opacities Classification System III) and gradings were made for nuclear opacities, nuclear color, cortical cataract and posterior subcapsular cataract. Spearman's rho:  $-0.134$   $p = 0.003$ . Spearman's rho: Men:  $-0.185$  ( $p=0.004$ ). Spearman's rho: Women:  $-0.078$  ( $p=0.214$ ).



**Figure 3** Correlation between visual acuity and cortical cataract in right eye. 560 70-year-olds in Gothenburg went through an eye examination including lens photographs and BCVA (best corrected visual acuity) measured according to ETDRS (Early Treatment Diabetic Retinopathy Study). The lens photographs were assessed by 2 ophthalmologists according to LOCS III (Lens Opacities Classification System III) and gradings were made for nuclear opacities, nuclear color, cortical cataract and posterior subcapsular cataract. Spearman's rho:  $-0.191$ ,  $p<0.001$ . Spearman's rho: Men:  $-0.179$  ( $p=0.006$ ). Spearman's rho: Women:  $-0.198$  ( $p=0.002$ ).

There were significant correlations between NC and impaired peripheral vision (Spearman's rho  $-0.154$   $p=0.01$ ), distance vision ( $-0.137$ ,  $p=0.002$ ), social functioning ( $-0.090$ ,  $p=0.046$ ), role limitations ( $-0.127$ ,  $p=0.005$ ), composite overall score ( $-0.107$ ,  $p=0.018$ ), Rasch activity limitations ( $-0.094$ ,  $p=0.038$ ), Rasch socio-emotional functioning ( $-0.108$ ,  $p=0.016$ ), Rasch total ( $-0.107$ ,  $p=0.018$ ), and between NO and distance vision ( $-0.111$ ,  $p=0.014$ ). There were borderline significant correlations between NO and peripheral vision (Spearman's rho  $-0.088$ ,  $p=0.051$ ).





**Figure 4** Correlation between visual acuity and posterior subcapsular cataract in right eye. 560 70-year-olds in Gothenburg went through an eye examination including lens photographs and BCVA (best corrected visual acuity) measured according to ETDRS (Early Treatment Diabetic Retinopathy Study). The lens photographs were assessed by 2 ophthalmologists according to LOCS III (Lens Opacities Classification System III) and gradings were made for nuclear opacities, nuclear color, cortical cataract and posterior subcapsular cataract. Spearman's rho:  $-0.129$ ,  $p=0.004$ . Spearman's rho: Men:  $-0.202$  ( $p=0.002$ ). Spearman's rho: Women:  $-0.048$  ( $p=0.444$ ).

## Discussion

There is no global definition of cataract and in various epidemiological studies diverse lens grading scales and cut-offs have been used, often including pseudophakia and aphakia, and occasionally including visual acuity.<sup>5–7,18</sup> This diversity can affect the accuracy when comparing the prevalence of cataract between different epidemiological studies.

LOCS III is one of the most common lens grading scales, and has been evaluated using objective methods of measuring lens opacities. Correlations between objective scatter index and nuclear, cortical and posterior subcapsular cataract have been found, using the double-pass Optical Quality Analysis System.<sup>19</sup> A linear increase between lens density as measured with the Pentacam Scheimpflug system and LOCS III score has been ascertained,<sup>20</sup> and the correlations between nuclear opalescence and objective scatter index and lens density have been confirmed in another study.<sup>21</sup> These analyses, using objective methods to quantify lens opacities and correlating them to LOCS-III, justify the use of a parametric statistical approach when analyzing LOCS-data.

In the Beaver Dam Eye Study, conducted in 1988–1990, the prevalence of cataract at the age of 65–74 years was 23.5% in women and 14.3% in men, and the prevalence of pseudophakia was 3.6%.<sup>22</sup> In the Blue Mountains Eye Study,<sup>5</sup> conducted in 1992–1994, the prevalence of cataract in age 65–74 years was 23.6% in women and 19.1% in men, and the prevalence of pseudophakia was 5.8% in women and 6.3% in men. The prevalence of cataract in the same age group in a Finnish study in 2000–2001 was 22.1%, more common in women than men, and unoperated cataract was more common in women than men.<sup>23</sup> These studies showed a lower prevalence of pseudophakia and cataract than in the present study, which can be explained by the increase in cataract surgeries in recent years.

Since increasing age is the most important factor for the development of cataract the comparisons of prevalence of cataract need to match the age of the participants.

In the Skövde Cataract study, the prevalence of cataract, including pseudophakia, at the age 70–74 years, was 23% in women and 21.5% in men.<sup>6</sup> The prevalence of pseudophakia was 9% in women and 9.5% in men, and women had significantly higher levels of NO, NC and CC in all age groups. Among people aged 75–79 years and for the total group of 70–84 years, women had significantly higher prevalence of cataract. When including pseudophakia women had significantly higher prevalence in the group aged 75–79 years, 80–84 years and in the total group. In our study, the prevalence of cataract, including pseudophakia, was higher than in the Skövde Cataract study, especially in women, which can be due to a higher

prevalence of pseudophakia in our study. The lens opacities were more severe in the Skövde Cataract Study in all cataract types, except for CC in men, which can be due to higher age in the participants. The increase in number of cataract surgeries, from 72'568 in 2006,<sup>24</sup> to 114'598 in 2014<sup>25</sup> combined with surgery at an earlier stage, when the visual acuity is higher and the lens opacities are less severe may explain the lower grade of lens opacities, and the higher prevalence of pseudophakia in our study, compared to the Skövde Cataract Study.

To use several assessors for the estimation of lens opacities is likely to increase the quality of the outcome. Interrater reliability in our study was in the moderate-substantial range. In the Beaver Dam Eye study,  $\kappa$  values were in the substantial range (0.65–0.75) for all cataract types.<sup>26</sup> In a study in Singapore,  $\kappa$  values between three observers were in the moderate range (0.41–0.60) initially and increased to substantial (0.61–0.80) after a standardization process.<sup>27</sup>

Self-reported cataract surgery has a high sensitivity and very high specificity in our study, matching numbers from the Los Angeles Latino Study.<sup>28</sup> Since cataract surgery in Sweden in recent years has been performed at earlier stages, cataract surgery could perhaps be used as a surrogate marker for clinically relevant cataract, particularly since the access to cataract surgery is good. The disadvantage of this approach is that the type of lens opacity is not diagnosed.

In the current study, self-reported diagnosis of cataract had a sensitivity of only 53% and a specificity of 92%. Other studies have shown similar or lower sensitivity and specificity,<sup>28–30</sup> including a study by Bowie which concluded that cataract surgery can be estimated with a questionnaire, but it is less accurate concerning cataract status, matching our conclusion.

The present study confirms that cataract, including pseudophakia, is more common in women than in men which confirms the findings in other studies.<sup>7,31</sup> Earlier studies have shown a higher level of cortical and nuclear opacities in women than in men<sup>4,5,7</sup> whereas in our cohort women had only slightly higher gradings in NO and NC than men.

The difference in pseudophakia between men and women is in accordance with previous studies, where the prevalence of cataract and pseudophakia is higher in women than men.<sup>7,31,32</sup> Logistic regression confirmed that female gender is a predictor for cataract and cataract surgery.

With an increasing number of cataract extractions in Sweden, from a number of 73'513 in 2001 to 139'665 in 2019, an increase in pre-operative visual acuity from 0.3 (decimal) in 2001 to 0.5 in 2019 was seen, paralleled by a decrease in the proportion of women from 66.1% in 2001 to 58.4 in 2019.<sup>2,33</sup> The gender differences in lens opacities that were previously seen have disappeared, whereas the prevalence of pseudophakia in women have increased. That the proportion of women going through cataract extractions have decreased in recent years may be explained by the dramatic increase in the total number of cataract extractions. The improvement in access to surgery have increased substantially for the majority of patients, in which the majority are women, who in earlier years had to wait longer for surgery.

That women have a higher prevalence of cataract than men can have different possible explanations: estrogens are thought to have anti-oxidative properties and protective effects against cataract, but when estrogen levels are dramatically reduced at menopause, the risk of developing cataract increases, i.e a withdrawal-effect.<sup>34,35</sup>

The participants showed good BCVA and high scores at VFQ-25 which may reflect good access to health care and surgery, also demonstrated by the high prevalence of pseudophakia. There have been concerns whether NEI VFQ-25 measures what it is intended to measure, and concerns that the questionnaire is multidimensional, meaning that not all questions included in a single score contributes to the measurement of a single construct.<sup>36</sup> Rasch analysis was therefore developed and, in our study, the Rasch analysis confirms the results from VFQ-25.

Lens opacities resulted in lower visual acuity but only slightly lower scores in VFQ-25. Other studies, when validating VFQ-25, showed lower scores and visual acuity in participants with cataract<sup>37,38</sup> which can be due to higher levels of lens opacities.

The pseudophakic group showed inferior results at VFQ-25 and a higher prevalence of other eye diseases. Since the differences in VFQ-25 disappear when excluding participants with other eye disease, the presumed reason for the inferior results could be comorbidity. For example, diabetic eye disease has been found to be a risk-factor for cataract<sup>26</sup> and diabetic patients might benefit less from cataract surgery.<sup>39</sup> Earlier studies have shown that the most frequent reason for “no-benefit” outcome after cataract surgery is a co-existing eye disease.<sup>40</sup> The higher prevalence of pseudophakia in people with other eye disease can also be due to obtaining a diagnosis of cataract at an earlier stage.

The study has some limitations: the subjective nature of diagnosing cataract and grading lens opacities, which could be made more objective using an objective method such as the Pentacam Scheimpflug system and the double-pass Optical Quality Analysis System. In a larger cohort, and possibly older participants, more participants would have cataract, which probably would result in greater distribution in VFQ-25 and NEI-VFQ-28-R. Possibly questioning about contrast acuity could detect subjective ailments in participants with cataract.

## Conclusion

The prevalence of cataract including pseudophakia in 70-year old people in the Gothenburg area is higher compared to a previous study in a similar geographical area,<sup>6</sup> and more common in women than in men. This could be due to the increasing number of cataract surgeries, that are performed at an earlier stage.<sup>3</sup> Validation showed very good agreement between pseudophakia assessed by lens photography and self-reported cataract surgery, whereas validation between diagnosis of cataract through examination and self-report showed high specificity but lower sensitivity. The results of BCVA and VFQ-25 are generally good. The results of this study are a good foundation for future studies about risk factors and cataract.

## Abbreviations

AL, activity limitations; ANOVA, analysis of variances; BCVA, best corrected visual acuity; CC, cortical cataract; CI, confidence interval; ETDRS, Early Treatment Diabetic Retinopathy Study Chart; IQR, interquartile range; LOCS, lens opacities classification system; NC, nuclear color; NEI VFQ-25, National Eye Institute Visual Functioning Questionnaire 25; NEI-VFQ-28R, National Eye Institute Visual Functioning Questionnaire 28; NO, nuclear opalescence; NPV, negative predictive value; PPV, positive predictive value; PSC, posterior subcapsular cataract; SD, standard deviation; SEF, socio-emotional functioning.

## Data Sharing Statement

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

## Author Contributions

LHJ performed the ophthalmic examination of 560 participants including visual acuity and lens photographs. MZ and MN analysed the lens photographs. MH did the Cohen's  $\kappa$  analysis and the sensitivity and specificity analyses. MN did the other statistical analyses and wrote the manuscript with contribution from MZ and MH. TRS, FA and HFE collected data in the H70 study including NEI VFQ-25 and information on cataract diagnosis and surgery from 1139 participants. IS is initiator and principal investigator of the H70 study. All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work.

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## Disclosure

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