


BMJ Open School performances in children with cataract: results from a population-based cohort study

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ABSTRACT

Objectives Childhood cataract is a chronic condition that may interfere with the child's learning capacities. We aimed to investigate whether childhood cataract influences academic development by comparing school performance in reading and mathematics in children with cataract to a matched control group.

Design Nationwide registry-based cohort study.

Settings Two surgical centres that perform all treatments for childhood cataract in Denmark.

Participants Children born between 2000 and 2009 diagnosed with cataract before 10 years of age (n=275) and an age-matched and sex-matched control group (n=2473).

Main outcome measures School performance was assessed as test scores in national tests performed at regular intervals from grade 2 to grade 8 in reading and mathematics. Analyses were corrected for birth origin, child somatic and mental disorder and parental socioeconomic status and mental disorders.

Results Of 275 children, 85 (30.9%) were operated for bilateral cataract, 79 (28.7%) unilateral cataract and 111 (40.4%) were not operated. We found that children with cataract have lower participation rate in the tests (62.5%) compared with the control cohort (77.2%) (p value=0.0001). After adjusting the pooled analyses for birth origin, somatic and mental disease in the child and parental socioeconomic status and mental disorders, we found that the children with cataract scored significantly lower in mathematics compared with those without cataract (mean difference=-4.78, 95% CI: -8.18 to -1.38, p value=0.006), whereas no difference was found regarding scores in reading (p=0.576). The lower score in mathematics was driven by children who had been operated for bilateral cataract (p-value=0.004).

Conclusion Children with cataract without somatic or neurodevelopmental comorbidities or psychosocial adversities seem to do well in school, whereas children operated for bilateral cataract have higher frequencies of difficulties in mathematical tasks.

INTRODUCTION

Congenital cataract is a chronic condition, which may be associated with congenital and severe systemic somatic disorders, for example, trisomy 21, neurodevelopmental disorders or congenital infections.¹⁻³ Bilateral

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ The study is a large cohort study based on a nationwide database on all children with cataract matched to a control group via national registries covering all citizens in Denmark.
- ⇒ The school test results were obtained by The Danish Agency of IT and Learning from all schools throughout the country, corrected by a digital system and reported to a central office in real-time.
- ⇒ We have adjusted for relevant confounders that were obtained from comprehensive national registries, and also adjusted for attrition bias.
- ⇒ Visual function may play an important role in school performance, but unfortunately, we did not have access to visual acuity measurements in the national databases, and hence it was not possible to include measures of visual function in the analyses.
- ⇒ Unfortunately, it was not possible to gain access to the exact reason for exemption from tests.

cataracts are often caused by genetic changes and they are also more often associated with systemic diseases, while unilateral cataracts are typically related to eye malformations or traumatic cataracts.^{1 2} These conditions may all potentially influence the child's learning capacities. Furthermore, children with cataract may face a range of particular challenges during their development, such as visual disability,⁴ or being absent from school due to frequent hospital visits including general anaesthesia events.⁵

Learning is a key element in a child's development and acquiring new skills is to a large extent dependent on visual recognition and cognitive processing of stimuli.⁶ Cognitive processing includes working memory, emotional regulation and planning skills. These functions are fundamental for the ability to learn and receive education.⁷ Education enables children to gain knowledge and to learn new skills including discipline, emotional self-regulation, critical thinking, interactional abilities and the

ability to reason, which are crucial components in social and emotional well-being throughout life.⁸ Reading skills are an important part of the overall learning process and rely on a complex interaction of visual and motor competences.⁹ Mathematical skills depend on visuomotor integration, attention and fine motor coordination.¹⁰ Reduced brain activity in areas associated to cognitive and attentive control has been identified in children with congenital cataract compared with children without cataract.¹¹ Together these factors may challenge school performance which may have a detrimental effect on life choices and possibilities.

Research data on school performance in children with cataract are limited except for a small study exploring school functioning on 201 children aged 8 years or older based on parents' reports.¹² The aim of the present study was to explore school performance in children with cataract compared with children without cataract using data from national registries.

MATERIALS AND METHODS

Study population

We evaluated test results of children with cataract born between 1 January 2000 and 31 December 2009 seen at Rigshospitalet, Copenhagen or Aarhus University Hospital. These two hospitals perform all treatments for childhood cataract in Denmark. The age of the children was chosen to ensure they were old enough to have been able to participate in the national Danish school tests from grade 2, see [figure 1](#) for details.

Children with cataract were divided into children with unilateral surgery, bilateral surgery and no surgery. Information about surgery laterality was obtained from medical records.

The children with cataract were compared with a cohort of children without cataract, who were matched by age, sex and municipality and sampled 1:10 from the general Danish population by Statistics Denmark.¹³

Study design

Data on school performance and socioeconomic factors were drawn from the national Danish registries which collect a number of variables real-time. In Denmark, each person has a unique identification number (Central Person Registry number), which makes it possible to extract information from a comprehensive set of national registries and to link children and parents, see online supplemental table 1 for an overview of registries used in the present study.

School performance: the Danish national tests

Information on school performance based on test scores in reading (grades 2, 4, 6 and 8) and mathematics (grades 3, 6 and 8) was obtained for years 2010–2018 from the *Danish Education Registry* and we evaluated the scores separately for each grade, and also pooled throughout the school years. The tests are conducted at regular intervals

throughout primary and secondary school and reported digitally to a central office, the Danish Agency of IT and Learning, from public and private schools including special classes (consisting children with disabilities) throughout the country.¹⁴ Children may be exempted from the national tests, for example, due to a mental or physical disability, at the discretion of the headmaster of their local school. Information on the reason for exemption is not available in the registries.

National tests have been used in Denmark since 2010.¹⁵ They evaluate the skills and knowledge in reading, mathematics, English language, geography, physics/chemistry and biology, on a numeric score scale from 1 to 100. The tests are conducted as a digital scoring test system containing different types of tasks at each grade and for each topic.

The tests in reading evaluate the child's ability to read and understand written text, for example, by recognising words illustrated in a picture (only at grade 2), choosing the right word in a context, understanding sentences in transferred meaning and to distinguish words in a line composed of words without spaces.

The tests in mathematics cover the ability to detect arrangements of shapes (eg, mirrored shapes), to understand figures, to navigate in spatial structures, to calculate probability of combinations, to add/subtract/divide random numbers without using a calculator, to visually recognise figures by description, to arrange numbers in decreasing/increasing order and to localise/mark the correct numbers in a line.

National registries

We used data from the national registries including *National Patient Registry* (NPR), which contains information about diagnostic and procedural ICD-10 codes on all contacts to public hospitals, as inpatient or out-patient and including emergency settings. The child's registered mental disorders diagnosed during the first 10 years of life were assessed using the ICD-10 diagnostic codes (F00–F99 and R41.8, R62.0, R62.9) listed in the NPR. In addition, any mental disorders diagnosed at a hospital (F00–F99) in one or both parents were assessed. The *Population Registry* was used to access information about sex, geographical birth origin and parental socioeconomic status. Information on parental work status was extracted from *Arbejdsklassifikationsmodulet* (AKM) *Registry* (work classification module), and parental income was obtained from the *Income Registry*. In addition, we extracted information on parental mental disorders from NPR, see online supplemental table 2 for details.

Confounders

The statistical analyses were corrected for the child's birth origin, somatic comorbidity,^{16–19} child's mental disorders,^{18 20} the parental socio-economic status^{21–25} and parents' mental disorders,^{26–28} as these factors may potentially affect school performance. The variables are described in-depth in online supplemental table 2.

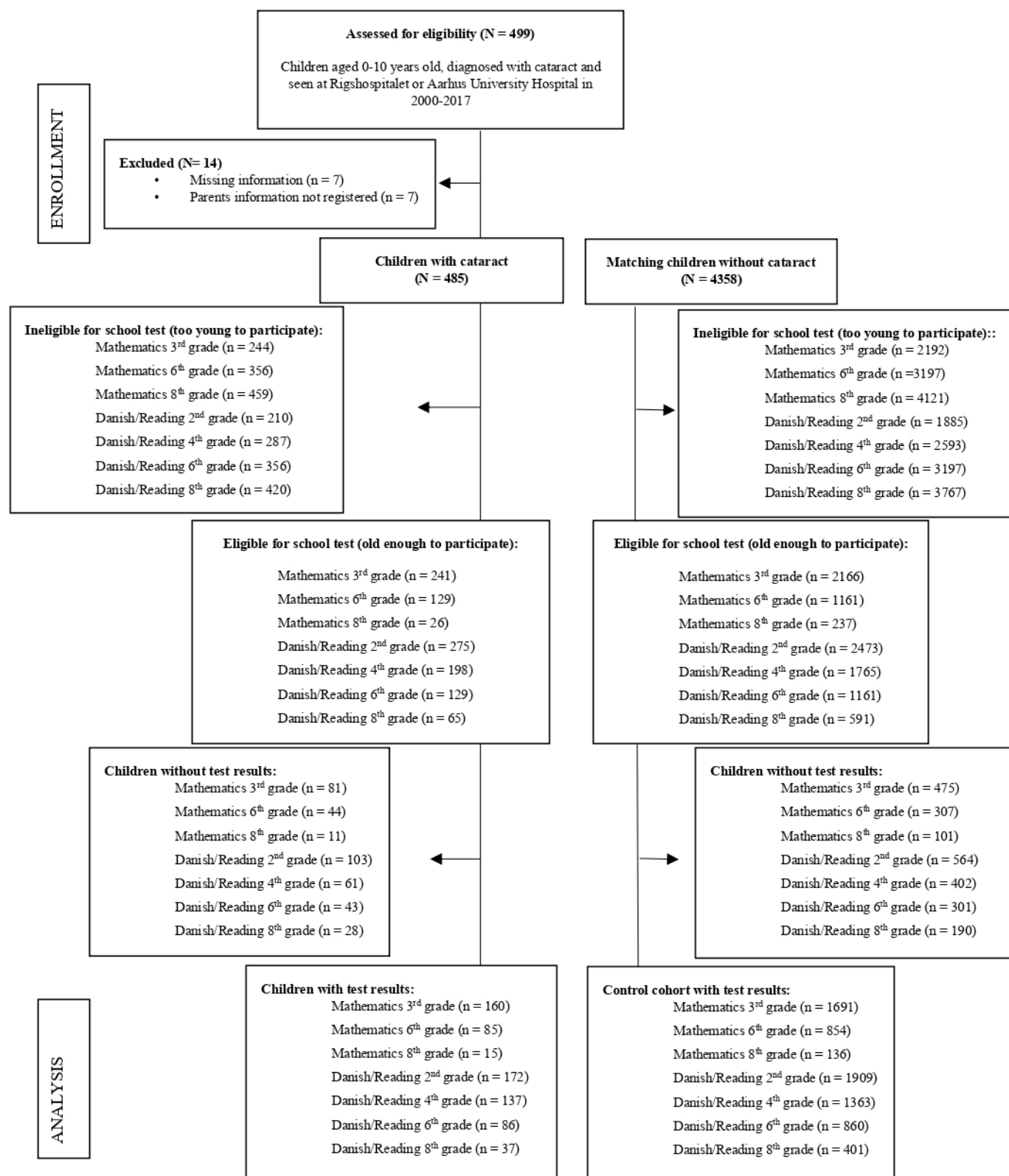


Figure 1 Flow chart showing eligible (old enough to participate) and ineligible children (too young to participate) and children with and without test results in the study population.

Patient and public involvement

None.

Statistical method

We used linear regression models to compare school test results in children with cataract, analysed both as a single group and subdivided by operation status, and the control cohort. We performed unadjusted analyses and analyses adjusted for the above listed confounders. The analyses were performed separately for the individual test results (grades 3, 6 and 8 mathematics and grades 2, 4, 6 and 8 reading), and longitudinally pooled on all test results obtained in mathematics or reading, respectively, where children could have up to three and four test results in the various grades. The latter are the main results of the paper, the former is available in the online supplemental files 3; 4. Since the profile of the children who did not have test results, for example, due to absence or exemption from the national test, may differ between the cataract and control cohorts, we weighted the available test results by the inverse probability of having a test result; these probabilities were estimated from a multivariable logistic regression including cataract status and the abovementioned confounders. The method of generalised estimating equations was used to adequately adjust the inference for the matching, the weighting and for excess correlation between the possible multiple times a child is in the data. Statistical analyses were made using the R software package, V.3.4.1 (The R Foundation for Statistical Computing, <http://www.r-project.org>). The significance level was set at <0.05 .

RESULTS

We included a total of 275 children with cataract (172 with test results), of which 85 (30.9%) were operated for bilateral cataract, 79 (28.7%) unilateral cataract and 111 (40.4%) were not operated due to visually insignificant cataracts. Their test results were compared with those of an age-matched and sex-matched control group ($n=2473$), see [figure 1](#) and [table 1](#).

A national test score was available in 172 (62.5%) children with cataract and 1909 (77.2%) in the control cohort. Thus, the proportion of children with a test score was significantly higher in the control cohort (p value=0.0001), see online supplemental table 3.

Children with cataract who did not have a test score had a greater prevalence of severe somatic disease (p value=0.014) and neurodevelopmental disorders (p value=0.008) and were more likely to have had bilateral surgery (p value=0.034) compared with children with cataract and available test scores, see [table 1](#).

We did not find significant differences in pooled test scores between children with cataract and children without cataract in reading (grades 2, 4, 6 and 8 pooled) neither in crude nor adjusted analyses, see [table 2](#).

The cataract cohort had significantly lower pooled test scores in mathematics (grades 3, 6 and 8 pooled)

compared with the control cohort, see [table 2](#). The lower test scores in mathematics were driven by those with bilateral surgery (mean difference=-8.98, 95% CI: -15.07 to -2.89, p value=0.004), while no significant difference was found for children with unilateral surgery or unoperated cataract compared with the control cohort.

Compared with children without cataract, the children in the cataract cohort were more often born outside Denmark (p value=0.020), and they suffered more often from severe chronic somatic illnesses (p value=0.00001). The parents of children with cataract had lower educational level (p value=0.0025), lower income (p value=0.021), were more often outside workforce (p value=0.00001) and had more often been diagnosed with a mental disorder (p value=0.031), see [table 1](#). The socioeconomic differences between the cataract and control groups did, however, not explain the difference in tests scores in mathematics, and they did not influence the results on reading either (adjusted analyses, see [table 2](#)).

The analyses for the individual tests, not pooled over the different grades, are shown in online supplemental table 4. Here we see that the assumption from the main analyses that the associations between cataract and school test scores are similar over the grades may not hold as significant differences are seen for children with bilateral operated cataract in reading grade 4 and grade 8 that are not found in the main analyses.

DISCUSSION

We evaluated school performance in children with cataract compared with age-matched and sex-matched children without cataract. The evaluation was based on national tests that are conducted at regular intervals throughout primary and secondary school and are reported to a central office, that is, we had access to a complete, national dataset. Thus, this study is the first to evaluate school performance in children with cataract based on a complete national dataset.

Using nationwide comprehensive register data on school performance and a range of potential confounders, we found that children with childhood cataract did not differ significantly from children without childhood cataract in the school performance regarding reading, while they scored lower in mathematics with the lowest scores seen in children who had undergone bilateral cataract surgery. It is important to note that one-third of the children with cataract had been exempted from the national tests which at least in part was explained by a higher prevalence of severe somatic and neurodevelopmental disorders found in children with cataract. While we attempted to adjust for this differential dropout in the statistical analyses, the test scores observed in the cohort have to be viewed as scores attained by the children with the highest educational abilities.

Although children in the cataract cohort generally came from families with lower parental education, income and work-force participation rate, the socioeconomic

Table 1 Characteristics of the study population

	Children with cataract		Children without cataract		P value *	Cataract children with test results		Cataract children without test results		P value *
	n=275	n=2473	n=275	n=2473		n=172	n=103	n=172	n=103	
Sex, girls/boys (%)	135/140 (49.1/50.9)	1235/1238 (49.9/50.1)	1235/1238 (49.9/50.1)	0.760		89/83 (51.7/48.3)	46/57 (44.7/55.3)			0.268
Age at cataract diagnosis (year), median (IQR)	3.85 (0.54–6.68) No surgery: 6.04 (3.14–8.04) Unilateral surgery: 3.20 (0.61–5.88) Bilateral surgery: 1.03 (0.20–4.36)	–	–	–		4.41 (0.90–6.67)	3.26 (0.23–6.70)			0.139
Age at cataract surgery (year), median (IQR)	3.66 (0.52–6.23) Unilateral surgery: 4.03 (1.09–6.66) Bilateral surgery: 2.00 (0.35–5.32)	–	–	–		3.85 (0.90–6.24)	2.51 (0.33–5.72)			0.328
Operated/non-operated, n (%)	164/111 (59.6/40.4)	–	–	–		94/78 (56.4/45.4)	70/33 (68.0/32.0)			0.502
Bilateral/unilateral surgery, n (%)	85/79 (51.8/48.2)	–	–	–		44/50 (46.8/53.2)	41/29 (58.6/41.4)			0.034
Child's birth place, n (%)										
Denmark	241 (87.6)	2270 (91.8)	2270 (91.8)	0.020		154 (89.5)	87 (84.5)			0.086
Outside Denmark	34 (12.4)	203 (8.2)	203 (8.2)			18 (10.5)	16 (15.5)			
Severe somatic diseases[†]										
Yes	13 (4.7)	6 (0.2)	6 (0.2)	<0.00001		6 (3.5)	7 (6.8)			0.014
No	262 (95.3)	2467 (99.8)	2467 (99.8)			166 (96.5)	96 (93.2)			
Mental disorders, n (%)										
Neurodevelopmental disorders [‡]	28 (10.2)	105 (4.3)	105 (4.3)	0.254		11 (6.4)	17 (16.5)			0.008
Other mental disorders§	14 (5.1)	79 (3.2)	79 (3.2)			8 (4.7)	6 (5.8)			0.779
Parental with basic education as the highest attained educational level, n (%)										
Parental income¶ (DKK), median (IQR)	35 (12.7) 211355.5 (149 766.1–267 318.4)	220 (8.9) 221 366.3 (168 334.7–277 568.1)	220 (8.9) 221 366.3 (168 334.7–277 568.1)	0.0025 0.021		18 (10.5) 208 778.02 (155 114.17–260 239.73)	17 (16.5) 192 633.89 (119 826.11–246 852.71)			0.709 0.037
Parental work status, n (%)										
Outside work force	37 (13.5)	144 (5.8)	144 (5.8)	<0.00001		18 (10.5)	19 (18.4)			0.066
One or both parent(s) at work	237 (86.2)	2328 (94.2)	2328 (94.2)			153 (89.0)	84 (81.6)			
Parental mental disorders										
None	240 (87.3)	2030 (82.1)	2030 (82.1)	0.031		149 (86.6)	91 (88.3)			0.349
One or both parent(s)	35 (12.7)	443 (17.9)	443 (17.9)			23 (13.4)	12 (11.7)			

Continued

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Enseignement Supérieur (ABES)

Table 1 Continued

Children with cataract	Children without cataract	P value *	Cataract children with test results	Cataract children without test results	P value *
n=275	n=2473		n=172	n=103	

The values with significance in Table 1 are in bold.

*P value: Pearson's χ^2 test for categorical variables, t-test for continuous variables.

†Severe somatic diseases: congenital syndrome—microcephaly, megalencephaly, Smith-Lemi-Opitz syndrome, trisomy 21, Down's syndrome, partial autosomal trisomy, Cytomegalovirus infection, interstitial lung disease, degenerative disease of the nervous system, congenital rubella infection, cancer in brain or meninges.

‡DF70–79, DF80–83, DF84, DF88–89, DF90, DR41.8, DR62.0, DR62.9.

§DF10–19, DF20–29, DF30–39, DF40–48, DF50, DF51–59, DF60–69, DF91–99.

¶11 Danish Krone corresponds to 0.13 Euro.

differences did not explain the difference between the groups. It should, however, be noted that the parental background in children with cataract with available test scores was more comparable to the parental socioeconomic status of the control cohort and that the negative social gradient was mainly observed for children with cataract who did not have a test score. Parental socioeconomic status and the home learning environment is known to play an important role in the child's school performance.^{21–25} Thus, significantly higher mathematical skills in kindergarten, and school grades 3 and 6 have been found among children from higher-income families compared with children from lower-income families.²⁹ The children with cataract who had a test score came from families with near-average socioeconomic status as most of those with lower socioeconomic background and comorbidities had not conducted the tests. In other words, our study shows that children with cataract who have no severe comorbidities or adverse family background compared with their healthy peers seem to perform nearly as well in school as children without cataract.

After adjusting for relevant confounders, we did not find differences in reading skills between children with and without cataract. Reading ability depends on decoding, working memory, listening comprehension and vocabulary.^{30 31} The cataract cohort was more likely to be born outside Denmark. At first it may seem surprising that their skills in Danish and reading was comparable to the control cohort; still, the proportion of children born outside Denmark was considerably higher among those without a test score.

We found a small but significant reduction in test score in mathematics (4.7 lower on a 0–100 scale) among children with cataract compared with children without cataract. Solving mathematical tasks requires a higher level of visuospatial performance (symbol cancellation and orientation, embedded figures and shape matching tasks) than reading.³² Visuospatial performance, eye–hand coordination and fine motor skills have been found to be reduced in school-aged children with other eye diseases (strabismus, amblyopia, cataract and/or nystagmus).^{33–36} The Infant Aphakia Treatment Study reported that preschool children with unilateral visual impairment due to unilateral cataract may have delayed motor functioning.³⁷ Visually impaired children have a lower school performance compared with children with good visual function.^{38 39} Unfortunately, data on visual performance were not available in the current national datasets. A recent Danish study has found that children aged 7–18 years who had been operated for bilateral cataract, scored lower on visual skills in the school environment when compared with children operated for unilateral cataract.⁴⁰ One of the main differences between children operated for bilateral cataract and children operated for unilateral cataract concern the possibilities of a healthy eye to support the operated eye in visual tasks. Children operated for unilateral cataract may have impaired depth perception, but this do not necessarily influence their national school test

Table 2 Mean scores in mathematics and reading in children with cataract compared with children without cataract

	Children with cataract	Children without cataract	Unadjusted†		Adjusted‡‡	
	Mean (SD)*		Mean difference (95% CI)	P value	Mean difference (95% CI)	P value
Reading						
Number of children (grades 2/4/6/8)	275/198/129/65	2473/1765/1161/591				
All	54.8 (25.4)	56.3 (23.7)	−1.57 (−4.55 to 1.40)	0.301	−0.71 (−3.21 to 1.79)	0.576
No surgery, n=111	55.7 (29.1)	–	−0.31 (−4.22 to 3.61)	0.879	1.76 (−2.00 to 5.52)	0.359
Unilateral surgery, n=79	53.5 (23.6)	–	−1.98 (−7.35 to 3.40)	0.472	−1.48 (−6.14 to 3.18)	0.533
Bilateral surgery, n=85	55.0 (24.1)	–	−2.72 (−8.92 to 3.47)	0.389	−3.62 (−7.96 to 0.72)	0.102
Mathematics						
Number of children (grades 3/6/8)	241/129/26	2166/1161/237				
All	52.7 (26.9)	56.7 (25.7)	−4.70 (−9.07 to −0.33)	0.035	−4.78 (−8.18 to −1.38)	0.006
No surgery, n=89	55.6 (28.6)	–	−5.25 (−10.46 to −0.03)	0.048	−3.10 (−8.40 to 2.20)	0.252
Unilateral surgery, n=68	48.9 (27.7)	–	−2.82 (−9.19 to 3.55)	0.385	−3.14 (−8.87 to 2.60)	0.284
Bilateral surgery, n=75	53.3 (25.2)	–	−5.62 (−15.95 to 4.71)	0.286	−8.98 (−15.07 to −2.89)	0.004

The unadjusted and adjusted results are pooled from the three math tests and the four reading tests, respectively.

The values with significance in Table 2 are in bold.

*Mean and SD are based on all eligible children. A child can take part in tests more than once. For example, for reading tests in the cataract cohort, 275/198/129/65 eligible children for grades 2, 4, 6 and 8 are indicated as eligible, which means that 65 children with cataract are in this analyses four times, 129–65=64 children with cataract are in this analyses three times, 198–129=69 children with cataract are in this analysis two times and 275–198=77 children with cataract are in this analysis one time.

†Unadjusted and adjusted analyses are based on a pooled evaluation of points in reading and mathematics, respectively.

‡Adjusted (using multivariable linear regression model) for the child's geographical birth origin, somatic comorbidity, mental disorders, the parental socioeconomic status and mental disorders.

results, which were all performed on a computer. Notably, the incidence of mental disorders has been shown to be increased in children with cataract with comorbid somatic diseases compared with children who have cataracts without comorbidities, underscoring the complexities of needs of care and support to these children.³ The high frequencies of systemic diseases and neurodevelopmental disorders seen in children with bilateral cataracts¹² underscore the necessity of rehabilitative activities and special training modules from early school life. Overall, early intervention and differentiated support systems are vital components to ensure the optimal development. Importantly, the visual function after childhood cataract surgery depends on access to visual and optical rehabilitation.

The incidence of mental disorders is increased in children with cataract who have somatic comorbidities compared with children who have isolated cataracts.³ As bilateral cataracts are often associated with other systemic diseases^{1 2} rehabilitative activities and special training modules adapted to the child from early school life may play a crucial role in how well they perform in school. Early intervention and comprehensive support systems are vital components in ensuring optimal development. Visual function after childhood cataract surgery

depends on access to visual and optical rehabilitation. In Denmark, the treatment of paediatric cataracts (≤6 years of age) is a highly specialised function that since 2010 has been managed by surgical centres at two sites: Rigshospitalet in Copenhagen and Aarhus University Hospital in Aarhus, where children are closely monitored by a highly specialised team consisting of low vision optometrists specialised in refractive rehabilitation of children with cataract, paediatric ophthalmologists and orthoptics. Appropriate optical correction through spectacles or contact lenses and the management of amblyopia are crucial aspects of maintaining good vision health. Early detection, intervention and regular eye examinations are important in addressing refractive errors and managing amblyopia to optimise visual acuity and prevents potential complications. Amblyopia treatment is usually stopped or markedly tapered after the age of 7.

To the authors' knowledge, only one study has been published so far in which school functioning has been reported in children with cataract.¹² A British Questionnaire Study evaluated the quality of life in 201 children aged 2–16 years who had undergone cataract surgery and found a lower level of school functioning based on answers completed by children and their parents.

Answers from children aged 8 years or older were based on a scale ranging from 0 (never a problem) to 4 (always a problem).¹² The British Study suggested that bilaterality of cataract tended to be associated with worse self-reported quality of life for physical and psychosocial, emotional and school domains. Correspondingly, in our nationwide register data on school performance based on national tests, we found the lowest scores in mathematics among children who had undergone bilateral cataract surgery. However, the term 'school functioning' was not elaborated in the British study which makes further comparisons difficult.

CONCLUSION

We evaluated school performance in children with cataract as this may potentially play an important role for their adult life choices. We found that more children with cataract had been exempted from the national school tests, and that those who did have test were more likely not to have systemic comorbidities and to come from a socio-economically favourable background compared with children with cataract who have no test score. Keeping that in mind, it is not surprising that we did not find a difference in readings skills between children with and without cataract and only a small difference in mathematical skills in pooled adjusted analyses. In other words, children with cataract who are otherwise healthy and without family adversities seem to do well in school even though they have chronic eye disease.

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Patient consent for publication Not applicable.

Ethics approval The study was approved by the Danish Data Protection Agency (RH-2016-336; I-Suite # 05070), and the Danish Patient Safety Authority (3-3013-1935/1/NAAN). According to the Committee on Health Research Ethics in the Capital Region of Denmark, ethical board review was not required (decision number: 16038234). The study followed the tenets of the Helsinki Declaration. exempted this study Participants gave informed consent to participate in the study before taking part.

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