

Vision status of children aged 7 - 15 years referred from school vision screening in Norway during 2003 - 2013: a retrospective study

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Abstract

Background: Undetected vision problems are an important cause of reduced academic achievement, performance in everyday life and self-esteem. This receives little attention in national health care services even though most of these vision problems are easily correctable. Data on how many schoolchildren are affected are limited. This study aims to increase the knowledge of vision status in primary and secondary school children by retrospectively describing the vision status of children referred from vision screening during the ten year period 2003 – 2013.

Methods: Of 1126 (15 %) children referred to the university eye clinic, all 782 who attended were included. Patient records were reviewed with regards to symptoms, refractive error, best corrected logMAR visual acuity (BCVA), binocular vision, ocular health and management outcomes.

Results: Previously undetected vision problems were confirmed in 650 (83 %) of the children. The most frequent outcomes were glasses (346) or follow up (209), but types of treatment modalities varied with age. Mean refractive errors were hyperopic for all age groups, but reduced with age (ANOVA, $p < .001$). Refractive errors did not change across the decade (linear regression, all $p > .05$). Mean BCVAs were better than 0.0 and improved with age (ANOVA, $p < .001$). The most prevalent symptoms were headaches (171), near vision problems (149), and reduced distance vision (107).

Conclusions: The vision screening identified children with previously undetected visual problems. There was no change in refractive errors for either age group over the decade. Importantly, most of the problems were solved with glasses. Types of visual problems varied with age, which stresses the importance of regular eye examinations, and raised awareness among parents and teaching staff.

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Background

We live in a visual world, and the ability to see effortlessly is something most people take for granted. The visual system changes in line with the growing child's expanding visual and behavioral world, and the majority develop good vision enabling us to learn, master and achieve important goals in different phases of life and to contribute in the society. In fact, good vision and eye health is a prerequisite step to the pathway of social, educational and economic independence and success [1-3].

Undetected vision problems is a major cause of reduced performance in everyday life, and for academic achievements and self-esteem [3-8]. Children are dependent on acquiring knowledge and skills through visual information, both in print and digital media, and by observing others. Children have to spend increasingly more time with their school- and homework as the academic requirements advance during school. At the same time, the font sizes in printed learning materials are gradually decreased. The fast development and use of digital technology further increase the visual demands at school [9, 10].

To keep up with learning and expected academic performance, children now need to spend more time reading and accessing digital information [11]. Further, children spend more time using digital devices in their spare time from a much earlier age [10-14]. This increases the workload on the visual system, especially the ability to sustain clear vision at near for longer periods at a time. Even problems such as small refractive errors, and accommodation or oculomotor control deficits can cause headaches, difficulty concentrating or poor coordination, and may lead to an unnecessary challenging time in school [15-18]. If a child avoids activities such as reading and homework, there will be serious consequences for the child's learning, academic and social success [2, 4, 19, 20]. This means that good vision is more important than ever, and that uncorrected vision problems should be identified.

In Norway all children aged 6 – 16 years have free, compulsory education provided in comprehensive schools, with one of the lowest pupil-teacher ratios (9:1) reported by the Organisation for Economic Co-operation and Development (OECD) [21, 22]. Both sexes have equal opportunity to education, the average number of years of education is 12.6, and most children (96%) are enrolled in pre-primary kindergardens [23]. The number of functional illiterates is low [24]. Norway was in 2018 ranked as number one in the global Human Development Index ranking (HDI) [23]. Primary health care in Norway is provided free of charge by the national health authorities until the age of 16 years [25]. Vision and eye health is included in the public preventative health care program up to the age of five years [26] in order to prevent irreversible vision loss, but vision examination is not included in school health care services.

The prevalence of visual problems in primary and secondary school children (6 – 16 years) in Norway is unknown, but a recent Norwegian study in 16 – 19 year olds found that more than half of these were hyperopes [27]. It is known that common vision problems such as refractive errors, heterophorias and accommodative disorders may have a profound effect on learning [28, 29]. Some of these conditions may be asymptomatic, and children are often not aware of their vision problems. Therefore children's vision problems may not be recognised by parents or teachers. In particular, hyperopia and near vision problems may only be detected through a thorough eye examination. Importantly, common vision problems are easy and cost-efficient to correct, and eye examinations should be considered for inclusion in school health services to promote learning, social interactions and future education, employment and socioeconomic benefits [2, 8, 20, 21].

There is little information of the visual status or extent of common vision problems in primary and secondary Norwegian school children. In Kongsberg, a school vision program has existed since the 1970s as a collaboration between the municipality and the National Centre of Optics, Vision and Eye Care (NCOVE) at the University of South-Eastern Norway. Here all school children are offered vision screening at the ages of 7, 10 and 15 years (2nd, 5th and 10th grade). This study aims to increase the knowledge of vision status in primary and secondary school children by retrospectively describing the vision status of children referred from vision screening during the ten year period 2003 – 2013.

Methods

Study Sample

The annual school vision screening program is a collaboration between Kongsberg municipality and NCOVE, and offers screening all children in 2nd, 5th and 10th grade (7, 10 and 15 year olds) in the 13 primary and secondary schools in Kongsberg. The majority of the school population has a Norwegian ethnic background (86 %) similar to the rest of Norway[30].

Participants

During the decade 2003 – 2013, 7658 children participated in the school vision screening program (94 % of all 8191 children eligible). Of these, 1126 (15 %) children failed the vision screening and were referred to the NCOVE university eye clinic for a full eye examination. This study has retrospectively analysed data from patient records of those 782 children who attended the NCOVE eye clinic. Several cohorts were screened two or three times, but only 40 (5 %) children were referred more than once. See flow chart for details (Figure 1). The study followed the tenets of the Declaration of Helsinki and was approved the Ombudsman for Privacy in Research at the Norwegian Social Science Data Services.

Protocol

The eye examination included a structured and age-appropriate history and symptoms interview. Refractive status was determined after retinoscopy and subjective refraction (at 6 m), generally obtained without cycloplegia, and best corrected visual acuity (BCVA) was recorded. Ocular alignment was assessed by cover test (6 m and 40 cm). Near point of convergence (NPC), and monocular and binocular accommodation amplitude (ACC) were assessed using a RAF-ruler. In addition, ocular motility, pupillary reactions, and ocular health were examined. The eye examination was performed by final year optometry students under supervision, and the supervisor had overall responsibility for choice of management and advice to the patient in line with the Norwegian Association of Optometry's clinical guidelines. Norwegian optometrists gained diagnostic drugs privileges by law in 2004, but cycloplegic refraction in children was not part of the standard procedure until the guidelines was revised in 2015.

For analysis, spherical equivalent refraction (SER) in diopters (D) was calculated. Refractive errors were defined as emmetropia ($-0.50 < \text{SER} < +1.00 \text{ D}$), hyperopia ($\text{SER} \geq 1.00 \text{ D}$), myopia ($\text{SER} \leq -0.50 \text{ D}$), astigmatism ($\leq -0.75 \text{ DC}$) and anisometropia ($\geq 1.00 \text{ D}$). Orthophoria was defined as 2 prism diopters (pd) exophoria to 1 pd esophoria for distance, and 6 pd exophoria to 0 pd esophoria for near. Normal NPC was defined as $\leq 10 \text{ cm}$ and normal ACC $\leq 10 \text{ D}$, $\leq 9 \text{ D}$ and $\leq 8 \text{ D}$ for the 2nd, 5th and 10th graders respectively. 34 children with strabismus were excluded from the binocular vision analysis. Symptoms were grouped into six categories. For details, see Table 2.

Management outcomes

The management and advice given to the patient were defined by five main categories: 1) prescription; 2) Vision training; 3) Follow up; 4) Referral to ophthalmologist and 5) False referrals (Table 2). Prescription were glasses or contact lenses. Vision training was conventional home based convergence-, accommodation- or facility training. Children with asthenopia or mild non-symptomatic hyperopia were scheduled for follow-up.

Statistical methods

Differences between groups were tested using the independent samples *t*-test. The threshold for statistical significance level was set at 5% ($p < .05$). Distributions and analyses using refractive errors include right eye (RE) only, as there were no significant differences between the right and left eyes (paired *t*-test, $p > .05$) for either age group, and SERs were normally distributed. All computations were performed using the statistical package SPSS Statistics 21 (International Business Machines, USA). Incomplete data sometimes occurred due to clinical considerations, explaining varying sample sizes for different parameters.

Results

Of the 1126 children referred, 782 (70 %) attended the eye examination, with 241 (31 %), 241 (31 %) and 300 (38 %) children in the three age groups (2nd, 5th and 10th grade).

Refractive error and visual acuity

Monocular and binocular spherical equivalent refractive errors (SER) (mean [95% CI]) are shown in Table 1. For all three age groups the mean SER was skewed towards hyperopia, and reduced significantly with age (ANOVA $F_2 = 26.8$, $p < .0001$, Tukey post-hoc analysis between all groups $p \leq .0001$).

Table 2 shows that most children were classified as emmetropic (60 %). Hyperopia $\geq +2.00$ D decreased with age, and was present in 7 % of the 2nd grade, 6 % of 5th grade, and 1 % of the 10th grade children. Myopia increased with age, with 3 % of 2nd grade, 15 % of 5th grade and 27 % of the 10th grade children being myopic. Although almost one third of 10th grade children were classified as myopic, only 1 % had myopia -3.00 D or higher. Clinically significant astigmatism (≥ 0.75 DC) was present in 5 % of all children, and clinically significant anisometropia (≥ 1.00 D) in 3 %.

The distribution of refractive errors was similar for all three age groups over the ten year period (Figure 2). Linear regression shows no significant change in either myopia or hyperopia with time for the 2nd grade ($R^2 = .01$, $F = 2.9$, $p > .05$), 5th grade ($R^2 = .01$, $F = 1.4$, $p > .05$) or 10th grade children ($R^2 = .002$, $F = .45$, $p > .05$).

Most children obtained very good correctable vision (BCVA, Table 1). As expected, binocular BCVA was slightly better than monocular. Overall, 91 % of children had BCVA of logMAR 0.0 (decimal acuity 1.0) or better in one or both eyes (Table 2). There was a slight but significant improvement with age (ANOVA $F_2 = 44.8$, $p < .0001$), and 2nd graders had lower visual acuity than both older age-groups (Tukey post-hoc analysis $p \leq .05$). Reduced vision was found in 2% of the children, including one 2nd grade child with BCVA > logMAR 0.5 (decimal acuity < 0.3), who was referred to an ophthalmologist due to ocular pathology.

Binocular vision and accommodation

Table 2 shows that distance and near horizontal orthophoria were present in 78 % and 77 % of children, respectively. The mean [95% CI] heterophoria was 0.8 [0.6, 1.0] exophoria for distance, and 2.3 [2.0, 2.6] exophoria for near. Exophoria was present in 13 % and 14 % of the children for distance and near, respectively (see Table 2 for criteria). Esophoria was less common, and present in 7 % and 9 % of children for distance and near.

Mean [95% CI] binocular accommodation was 14.0 [13.4, 14.6] D, 12.9 [12.3, 13.5] D, and 11.8 [11.3, 12.2] D for 2nd, 5th and 10th graders, respectively (Table 1), and reduced binocular accommodation was found in 15 % of all children (Table 2). ANOVA and post-hoc analyses showed a significant difference in accommodation between the three age groups for binocular measures (ANOVA $F_2 = 18.9$, $p < .0001$, Tukey $p \leq .007$ for all comparisons). Near point of convergence (NPC) was 8.2 [7.7, 8.7] cm across all children, and NPC ≥ 10 cm was found in 19 %. There was no significant difference between the age groups for NPC (ANOVA $F_2 = .241$, $p = .786$).

Symptoms

Of the 782 children, 26 % experienced symptoms of vision problems, and 25 % had more than one symptom. The most prevalent symptoms were headaches (22 %), near vision problems (19 %) and reduced distance vision (14 %).

Management

Most children (650, 83 %) referred from the school screening had vision problems requiring treatment or follow up. Glasses for distance or near work was the most common management strategy (55 %), followed by vision training (7 %) and glasses combined with vision training (4 %). Glasses were recommended primarily for low hyperopia in 2nd and 5th grade and for myopia in 10th grade children. Binocular vision- and near problems due to reduced accommodation or poor NPC were prescribed low plus lenses, vision training or both. Of the 16 % of children with reduced accommodation, 42 % were given glasses, 19 % prescribed vision training and 11 % a combination. For the 14 % of children with reduced

NPC, 40 % were given glasses, 31 % vision training and 20% both glasses and training. Vision training was more commonly recommended for 5th and 10th grade children, while the 2nd grade children were more likely to receive follow up. Follow up (33 %) was recommended when the child had borderline symptoms, refractive errors or binocular findings and no immediate management was required. Overall 25 (4 %) children were referred to an ophthalmologist, however, most were 2nd grade children requiring glasses to be covered by the National Insurance Scheme.

Discussion

This study describes vision status based on a comprehensive eye examination in 782 of 1126 (70 %) children referred from the Kongsberg vision screening program where 7658 2nd, 5th and 10th grade children attended during 2003 – 2013. Most children had normal functional vision and eye health. As expected, there was a slight but significant improvement in best corrected visual acuity with age, and only a few children had reduced visual acuity. However, of those 782 attending the eye examination, 83 % were confirmed to be true referrals, indicating that the vision screening program identified vision problems previously not detected. This suggests that many children, parents and teachers are unaware of vision problems that may influence academic performance and quality of life, which supports previous studies [2, 4, 15-17, 20, 31, 32].

Importantly, our study confirms that most vision problems can easily be managed by glasses or vision training [31-33]. A substantial proportion of the children had low to moderate hyperopia, or accommodative or binocular deficits. These deficits may interfere with the ability to do sustained near work [17, 18, 34, 35], but can be difficult to detect because of normal distance vision and absence of explicit symptoms. As children spend a considerable time with near activities at school and their spare time [10, 13], eye and vision examinations should be available through the school health care services to prevent unnecessary academic achievement gaps.

Even if most children in this study were emmetropic, all age groups showed a slight hyperopic mean refractive error which reduced with age, as expected [36-40]. Interestingly, we did not find any change in refractive errors during the ten year period for either age group, nor did we find the high proportion of myopia reported in many studies [41-46]. Although we found that myopia increased with age, only four children (1 %) had myopia higher than 3.0 D (SER). The relatively low proportion of myopia supports previous studies showing that hyperopia is frequent in Nordic children and youths [27, 47, 48], and implies that refractive status has been relatively stable over the past few decades. This is also similar to data reported in white American children [40, 49]. One limitation to the reported refractive errors in this study is that cycloplegic refraction was not routinely used, as this was not considered standard clinical practice for school children in Norway until 2014. However, a cycloplegic refraction would skew the refractive error for all age groups towards higher values of hyperopia, and as such the values and numbers of hyperopia in our study would be increased.

Most children had good accommodation and binocular vision, but a proportion were given glasses or vision training. Accommodation and binocular vision problems may cause symptoms like headache, eyestrain, blurred vision, intermittent diplopia, poor concentration and comprehension when performing near tasks [18, 35, 50-52]. Further, children do not necessarily complain of symptoms if not asked specifically. It is likely that a substantial portion of the children found to have vision problems in this study would have remained undiagnosed in absence of the vision screening.

Our results show that children at different age groups have different visual challenges in need of different treatments. Academic achievements and success depend on effective and efficient reading and learning. Vision changes in addition to increased visual demands in school with age, and eye examinations at regular intervals should be emphasized. This study suggests that children would benefit from a comprehensive vision examination during the second, fifth and tenth grade at school, as this is likely to promote academic success and social inclusion. Further it would educate and raise awareness among children, parents and teaching staff of the importance of good vision for good health.

A strength of this study is the large stable number of children attending the eye examination. The vision problems remain similar over the decade, which limits the effect of bias and contribute to the validity of this study. Furthermore, the Kongsberg school population has a Norwegian ethnic background similar to the rest of Norway, and the school vision screening has a very high attendance (94% of the population). This strengthens the potential generalizability of the study results to all Norwegian school children of the same age. A limitation of the study is the large amount of data collected over a long period by different optometry students which may have influenced the quality of results and missing data, but in all cases they were supervised and managed by experienced optometrists, and the results are comparable to other Nordic countries. Despite this, the study contributes important knowledge of the vision status and problems in school children that may guide further research, clinical practice and healthcare policies to include vision in school health care as this receives little attention both in Norway, but also in other countries [53, 54].

Conclusions

Even if most children attending the eye clinic had good vision, at least 11 % of the population screened during 2003 – 2013 had previously undetected vision problems. Importantly, these vision problems are easily corrected with glasses or vision training at a low cost. The types of vision problems differed with age, but in all age groups, most children had emmetropia or mild hyperopia, and there was no change over the decade. Our results suggests that a large proportion of school children, and their parents, may not be aware of vision problems which potentially have a negative impact on their performance at school. If left alone, this may lead to drop out and reduced participation in society. Therefore, raising awareness of the need for regular eye examination throughout primary and secondary school with teachers and school nurses, and including eye and vision examination in school health care services, will reduce the number of school children with avoidable vision problems and potential socioeconomic burden and may improve quality of life

Abbreviations

ACC: accommodation, BCVA: best corrected visual acuity, BIN: binocular, cm. centimeter D: Diopters, LE: left eye, m: meter, MAR: minimum angle of resolution, NCOVE: National Centre for Optics, Vision and Eye Care, NPC: Near point of convergence, pd: prism diopters, RE: right eye, SER: spherical equivalent refraction, VT: Vision training

Declarations

Ethics approval and consent to participate

The study followed the tenets of the Declaration of Helsinki. Data collection was organized digitally while taking care of appropriate data protection. The confidentiality of participants is protected by using an encryption key prior to data analyses. The key was stored separately from study data. All data was treated according the Ombudsman for Privacy in Research at the Norwegian Social Science Data Services.

Consent for publication

Not applicable

Availability of data and material

The datasets analysed during the current study are available from HKF on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

HKF designed the study, analyzed and interpreted the data and wrote the first draft of the manuscript. ES made significant contributions to data analyses and interpretations and manuscript preparation. TL contributed to data interpretation and critically revising the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1. Mean [95 % CI] refractive error, best corrected visual acuity and accommodation amplitude for 2nd, 5th and 10th grade children, shown for right and left eye (RE, LE) and binocular (Bin) measurements.

		2 nd grade	5 th grade	10 th grade
		Mean [CI]	Mean [CI]	Mean [CI]
Refraction (SER)	RE	+0.71 [0.61, 0.82]	+0.46 [0.32, 0.60]	+0.07 [-0.05, 0.19]
	LE	+0.76 [0.65, 0.86]	+0.51 [0.36, 0.66]	+0.08 [-0.03, 0.20]
Best corrected visual acuity (logMAR)	RE	0.01 [-0.002, 0.02]	-0.04 [-0.06, -0.02]	-0.05 [-0.06, -0.04]
	LE	0.02 [0.001, 0.03]	-0.04 [-0.05, -0.03]	-0.06 [-0.07, -0.04]
	Bin	-0.02 [-0.04, -0.03]	-0.09 [-0.10, -0.07]	-0.10 [-0.11, -0.09]
Accommodation amplitude (D)	RE	12.3 [11.7, 12.9]	11.4 [10.8, 12.0]	10.3 [9.9, 10.7]
	LE	12.4 [11.8, 13.0]	11.5 [10.9, 12.0]	10.5 [10.2, 10.9]
	Bin	14.0 [13.4, 14.6]	12.9 [12.3, 13.5]	11.8 [11.3, 12.2]

Table 2. Sample description of demographics, eye examination results, self-reported symptoms and management (n = 782)

		All <i>n</i> = 782 <i>n</i> (valid %)	2 nd grade <i>n</i> = 241 (31) <i>n</i> (valid %)	5 th grade <i>n</i> = 241 (31) <i>n</i> (valid %)	10 th grade <i>n</i> = 300 (38) <i>n</i> (valid %)
Referred	Males	336 (43)	107 (44)	103 (43)	128 (43)
	Females	446 (57)	136 (56)	138 (57)	172 (57)
Ametropia RE (SER, D)	Emmetropia (> -0.50D, < +1.00D)	470 (60)	148 (62)	145 (60)	177 (59)
		150 (19)	65 (27)	47 (19)	38 (13)
	Hyperopia (≥ +1.00D, < +2.00D)	34 (4)	17(7)	13 (6)	4 (1)
	Hyperopia (≥ +2.00D)	125 (16)	8 (3)	36 (15)	81 (27)
	Myopia (≤ -0.50 D)	5 (1)	0	1 (0)	4 (1)
	Myopia (≤ -3.00 D)				
	Anisometropia (≥ 1.00 D)	13 (2)	1 (0)	6 (2)	6 (2)
Astigmatism (≥ -0,75 DC)	40 (5)	12 (5)	10 (4)	18 (6)	
BCVA RE	LogMAR (≤ 0.0)	699 (91)	191 (82)	220 (94)	288 (96)
	LogMAR (≤ 0.1, > 0.0)	50 (7)	32 (14)	13 (6)	5 (2)
	LogMAR (< 0.5, > 0.1)	17 (2)	10 (4)	1	6 (2)
	LogMAR (≥ 0.5)	1	1	0	0
Horizontal heterophoria distance (6 m)	Orthophoria	579 (78)	168 (74)	180 (80)	231 (82)
	Exophoria > 2 pd	94 (13)	46 (20)	33 (15)	27 (9)
	Esophoria > 1 pd	51 (7)	14 (6)	11 (5)	26 (9)
Horizontal heterophoria near (40 cm)	Orthophoria	563 (77)	171 (75)	174 (78)	218 (76)
	Exophoria > 6 pd	100 (14)	33 (14)	22 (10)	45 (16)
	Esophoria > 0 pd	74 (9)	24 (10)	27 (12)	23 (8)
Vertical heterophoria	Present > 3 pd	5 (0)	0	2 (0)	3 (1)
Strabismus	Present	34 (4)	13 (5)	1 (0)	20 (7)
NPC (cm)	≤ 10 cm	640 (82)	200 (88)	196 (85)	240 (82)
	> 10 < 25 cm	78 (10)	14 (6)	24 (10)	40 (14)
	≥ 25 cm	34 (4)	13 (6)	10 (4)	11 (4)
Accommodation (D)	Reduced ACC*				
	RE	200 (26)	66 (30)	62 (27)	72 (25)
	LE	203 (26)	67 (30)	69 (30)	67 (23)

	BIN	126 (16)	41 (19)	43 (19)	42 (14)
Ocular pathology	Present	14 (2)	3 (1)	5 (2)	6 (2)
Symptoms	Headaches	171 (22)	37 (15)	59 (24)	74 (25)
	Near vision problems	149 (19)	41 (19)	51 (21)	57 (19)
	Reduced distance vision	107 (14)	26 (11)	28 (12)	53 (22)
	Facility problems	62 (8)	5 (2)	18 (7)	39 (13)
	Tired eyes	55 (7)	10 (4)	16 (7)	29 (10)
	Diplopia	4 (0)	2 (1)	2 (1)	0
Management	Prescription	346 (55)	60 (25)	116 (48)	170 (57)
	Vision training (VT)	45 (7)	10 (4)	18 (7)	17 (6)
	Prescription and VT	25 (4)	3 (1)	10 (4)	12 (4)
	Follow up	209 (33)	88 (37)	58 (24)	63 (21)
	Referral ophthalmologist	25 (4)	14 (6)	5 (2)	6 (2)
	False referral	132 (17)	66 (27)	34 (14)	32 (11)

*Criteria for reduced ACC $\leq 10 D$, $\leq 9 D$, $\leq 8 D$, for 2nd, 5th and 10th grades, respectively.

Figures

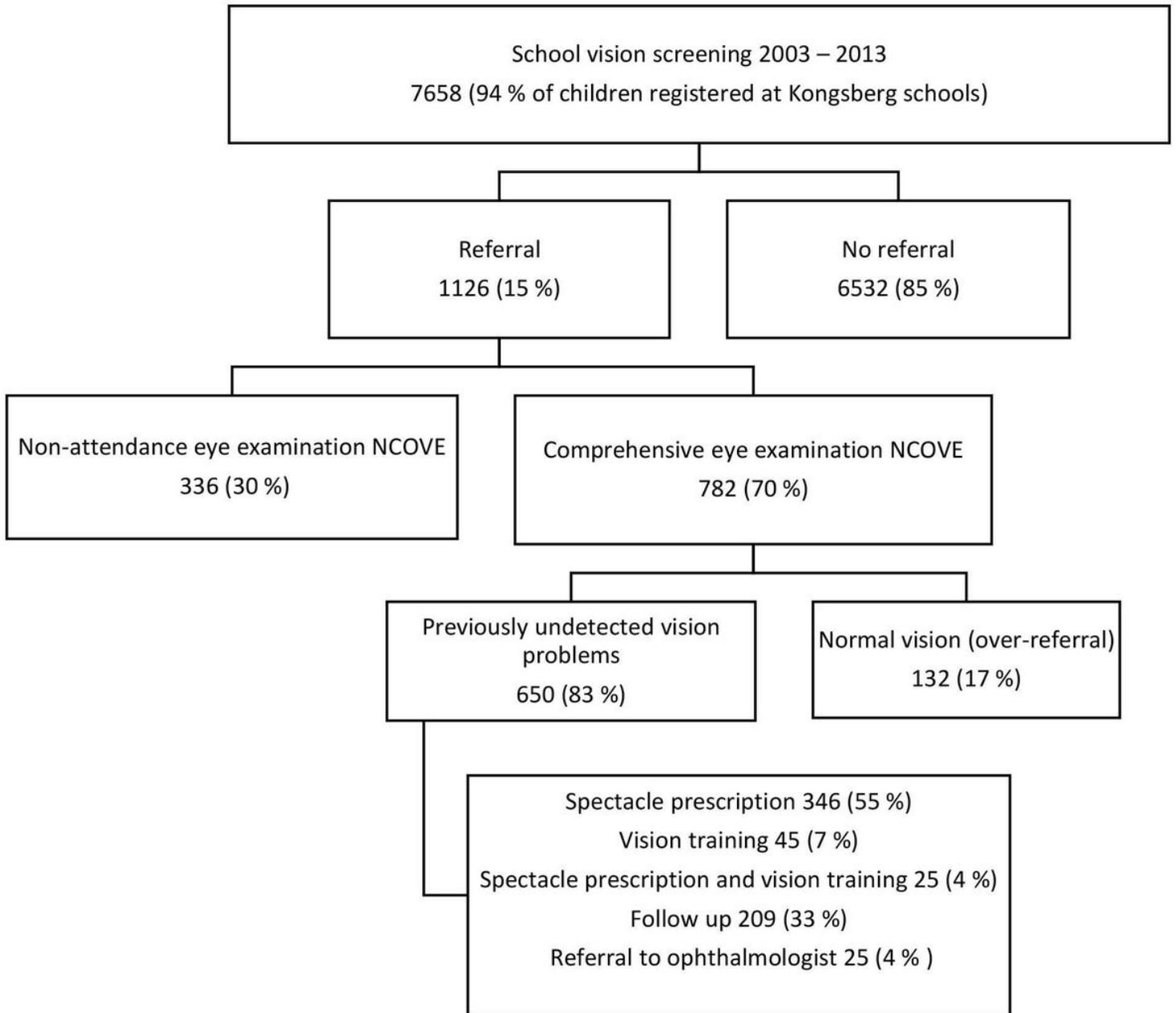


Figure 1

Flow chart of the visual outcome from the Kongsberg vision school screening for 2nd, 5th and 10th grade during the period 2003 – 2013. In each box, the number and percentage of children are reported.

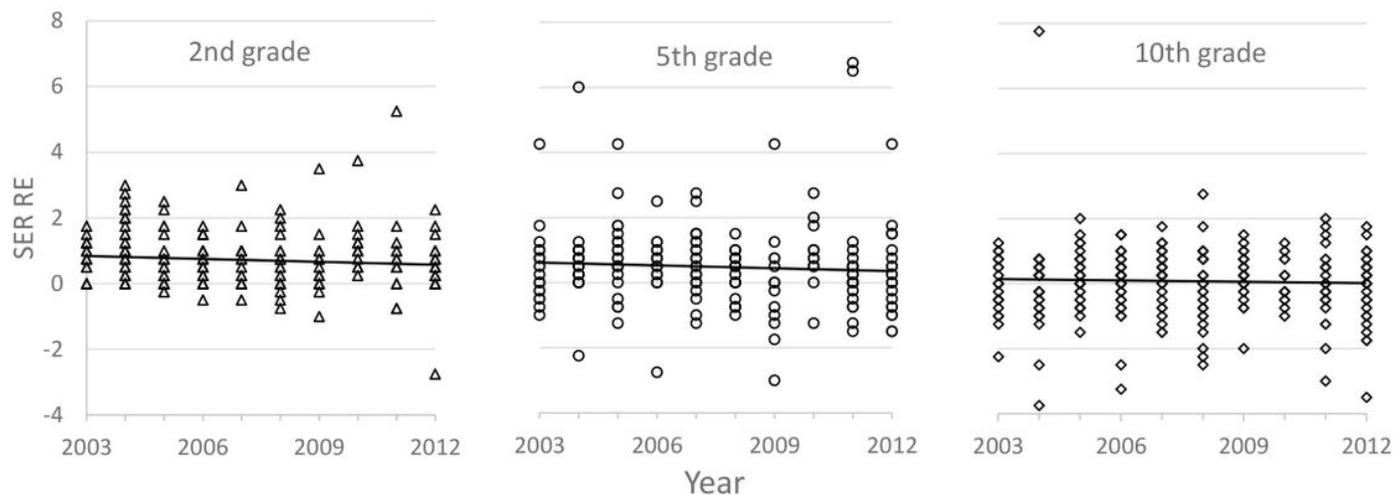


Figure 2

Scatterplot showing right eye spherical refractive errors (SER) in diopters for each age group (2nd, 5th, and 10th grade) as a function of time for each year 2003–2013. Points show individual children (several overlap), and lines show fitted linear regression lines.