Association of Strabismus With Functional Vision and Eye-Related Quality of Life in Children

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IMPORTANCE Strabismus is common, affecting 2% to 4% of children, but how children and their families are affected in everyday life is poorly understood.

OBJECTIVE To evaluate the association of strabismus with functional vision and eye-related quality of life in children and their families using the Pediatric Eye Questionnaire (PedEyeQ).

DESIGN, SETTING, AND PARTICIPANTS This cross-sectional study was conducted between December 2017 and October 2019 and included 91 children with strabismus and 166 visually normal controls across 3 age groups (0-4, 5-11, and 12-17 years) who were enrolled at Mayo Clinic, Rochester, Minnesota, and Retina Foundation of the Southwest, Dallas, Texas.

EXPOSURES Children completed the child PedEyeQ (5 to 11- and 12 to 17-year versions: functional vision, bothered by eyes/vision, social, and frustration/worry domains); parents completed the proxy (0 to 4-, 5 to 11-, and 12 to 17-year versions: functional vision, bothered by eyes/vision, social, frustration/worry, and eye care domains) and the parent PedEyeQ (impact on parent and family, worry about child's eye condition, worry about child's self-perception and interactions, and worry about child's functional vision domains). Rasch-calibrated PedEyeQ scores were calculated for each domain and converted to 0 (worst) to 100.

MAIN OUTCOMES AND MEASURES PedEyeQ domain scores

RESULTS Of 91 participants with strabismus, 41 (45.1%) were girls, 74 (81.3%) were white, 4 (4.4%) were Asian, 5 (5.5%) were more than 1 race, 5 (5.5%) were African American, and 2 (2.2%) were American Indian/Alaska Native. Child PedEyeQ domain scores were lower with strabismus vs visually normal controls among children ages 5 to 11 years and the greatest mean (SD) difference was in functional vision (12 [14] points; 95% CI, 6-18; \( P = .001 \)), and among children ages 12 to 17 years, the greatest mean (SD) difference was in frustration/worry (27 [13] points; 95% CI, 18-36; \( P < .001 \)). Proxy PedEyeQ domain scores were also lower with strabismus. The greatest difference among children ages 0 to 4 years was in functional vision (13 [9] points; 95% CI, 9-16; \( P < .001 \)), among children ages 5 to 11 years was in functional vision (26 [10] points; 95% CI, 22-30; \( P < .001 \)), and among children ages 12 to 17 years was in functional vision (21 [12] points; 95% CI, 12-30; \( P < .001 \)), social (21 [13] points; 95% CI, 12-30; \( P < .001 \)), and frustration/worry (21 [13] points; 95% CI, 12-30; \( P < .001 \)). Parent PedEyeQ domain scores were lower with strabismus; the greatest difference was in worry about child’s eye condition (38 [14] points; 95% CI, 34-42; \( P < .001 \)).

CONCLUSIONS AND RELEVANCE Strabismus is associated with reduced functional vision and eye-related quality of life in children. Parents of children with strabismus also experience a reduced quality of life. These findings advance our understanding of how strabismus affects children and their families and should be considered when defining patient management goals.
Strabismus (ocular misalignment) is a common pediatric eye condition, affecting between 2% to 4% of developmentally normal children1-3 and most often manifests as an esodeviation (inward turning) or an exodeviation (outward turning). In previous studies, strabismus has been reported to be associated with reduced general health-related quality of life (HRQOL)4,5 and eye-related quality of life (ER-QOL)6-10 However, these previous studies are limited by their use of instruments that were either generic,4,5 not designed for children,6,7 created for a specific subtype of strabismus,8,9,10 or for which development methods were not described.8 We recently developed the Pediatric Eye Questionnaire (PedEyeQ),11 a child- and parent-derived, Rasch-scored, age-specific measure of functional vision and ER-QOL designed for children with any eye condition and their parents. In the present study, we compared PedEyeQ scores in children with strabismus and normal controls, hypothesizing that the presence of strabismus would result in lower functional vision and ER-QOL. In secondary analyses, we evaluated general HRQOL using the Pediatric Quality of Life Inventory (PedsQL),12 hypothesizing that there would be a weaker association of strabismus with general HRQOL. We anticipated that the study findings would advance the understanding of how strabismus affects children and their families, helping to refine the aims of clinical management and identify areas for future research.

Methods
Approval was obtained from institutional review boards at the Mayo Clinic (Rochester, Minnesota) and the University of Texas Southwestern Medical Center (Dallas, Texas). All procedures and data collection were conducted in a manner compliant with the US Health Insurance Portability and Accountability Act and all research procedures adhered to the tenets of the Declaration of Helsinki. Written informed consent and assent were obtained according to local institutional review board requirements. Consecutive eligible children with strabismus were prospectively enrolled from pediatric ophthalmology outpatient clinics at a tertiary medical center (Mayo Clinic, Minnesota) and in research clinics (Retina Foundation of the Southwest, Texas) between December 2017 and October 2019. Families were offered $40 in remuneration for their time. Few patients declined participation but for those who did it was primarily because of a lack of time to complete the questionnaires.

Children With Strabismus
Eligible children were aged 0 to 17 years with a current diagnosis of strabismus that was classified as either esotropia or exotropia and measured 10 or more prism diopters (PD) at distance or near by a simultaneous prism cover test. If simultaneous prism cover test data were not available, or if the child had intermittent strabismus, the prism and alternate cover test measurement was used. Children with developmental delay were included, although not all such children were able to complete child questionnaires.

PedEyeQ
The PedEyeQ is a child-derived,16-19 Rasch-analyzed,14 functional vision and ER-QOL questionnaire composed of child, proxy, and parent components, each with distinct, separately scored domains. Questions in each domain use a 3-point frequency scale for responses: (1) never, (2) sometimes, or (3) all of the time. (Full questionnaires, in English and Spanish, with Rasch-scoring lookup tables are freely available at https://public.jaeb.org/pedig/view/Other_Forms.)

Key Points
- **Question** How is childhood strabismus associated with the functional vision and quality of life of affected children and their parents as assessed using the newly developed Pediatric Eye Questionnaire?
- **Findings** In this cross-sectional study, we found that children with strabismus had lower functional vision and eye-related quality of life compared with visually normal healthy controls across multiple domains. Parents of children with strabismus also experienced a reduced quality of life compared with parents of visually normal controls.
- **Meaning** The association of strabismus with functional vision and eye-related quality of life in children should be considered when defining management goals.

The description of the current strabismus type was based on review of the medical record. Previous strabismus surgery was allowed, as were coexistent diagnoses of eye conditions commonly associated with strabismus, including amblyopia, refractive error, and manifest-latent nystagmus in the context of infantile esotropia. We also allowed clinically insignificant diagnoses, such as previous (resolved) nasolacrimal duct obstruction, or dot cataract, but significant coexistent eye conditions were excluded.

Visualy Normal Controls
Children with normal visual acuity, no refractive correction, and no current or previous eye disease or treatment were enrolled to complete the PedEyeQ as visually normal controls. Because normal visual acuity thresholds vary by age, we used previously published age-referenced normal visual acuity data13,14 to confirm that visual acuity was normal for age, including Teller acuity cards in young children.15

Questionnaires
Children with strabismus and normal controls completed the child PedEyeQ and the child PedsQL (if aged 5-17 years and able) and 1 parent or legal guardian for each child completed the proxy and parent PedEyeQ as well as the proxy PedsQL and the PedsQL Family Impact Module. Most children/parents completing questionnaires did so electronically on an iPad (Apple), with others completing it on paper. For parents and older children, questionnaires were self-administered; for younger children, questionnaires were completed with help from a member of the research team.

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The child PedEyeQ has 5- to 11- and 12- to 17-year versions, each with 4 distinct, separately scored domains: functional vision, bothered by eyes/vision, social, and frustration/worry (there are some differences in questions between age-specific versions). The proxy PedEyeQ has 3 age-specific versions: ages 0 to 4 years (functional vision, bothered by eyes/vision, and social domains), 5 to 11 years, and 12 to 17 years (both with 5 domains: functional vision, bothered by eyes/vision, social, frustration/worry, and eye care; there are some differences in questions between age-specific versions). The parent PedEyeQ assesses how the child's eye condition affects the parent themselves in 4 domains: impact on parent and family, worry about child's eye condition, worry about child's self-perception and interactions, and worry about child's functional vision.

PedSQL
The PedSQL is a general HRQOL questionnaire. For the present study we used the child module (5 to 7-, 8 to 12-, and 13 to 17-year-old versions, each with 23 items in 4 domains: physical, emotional, social, and school functioning), proxy module (parallel to the child versions for children age 5–17 years, with some differences in items included in the 2- to 4-year version) and the PedSQL Family Impact Module (8 domains). Each of the individual pediatric questionnaires had 5 response options. The PedSQL questionnaires use 3 response options with the exception of the child 5 to 7 years old, which uses 3 options (http://www.pedsqol.org/about_pedsqol.html).

Analysis
PedEyeQ
For each participant, on each distinct PedEyeQ domain, Rasch scores were calculated using previously published Rasch lookup tables and converted to 0 (worst) to 100 (best) for interpretation. Domain scores were calculated as a mean of all completed items (most participants completed questionnaires on an iPad, ensuring completion of all items). The primary analysis was a comparison of median PedEyeQ scores between children with strabismus and visually normal controls. P values were not adjusted for multiple comparisons and a 2-sided test was used with significance set at P < .05.

To address the possibility that findings in children with strabismus may be confounded by coexistent amblyopia, eyeglasses wear, or previous strabismus surgery, we identified a subgroup of children age 5 to 11 years without current amblyopia, eyeglasses wear, or history of strabismus surgery and compared PedEyeQ scores with normal controls aged 5 to 11 years (insufficient numbers precluded similar analyses in other age groups).

PedSQL
For the analysis of PedSQL data, only children ages 2 to 17 years were included (there were insufficient numbers in the proxy 0- to 12-month and 13- to 24-month groups). Individual domain scores were calculated for the PedSQL questionnaire according to instructions (yielding a 0 [worst] to 100 [best] score). Scores were compared between children with strabismus and normal controls.

Differences between groups were assessed primarily using nonparametric Kruskal-Wallis tests. To represent the precision of our estimates of difference, we also calculated mean differences with a 95% CI around the mean difference. In some cases, the 95% CI appeared to indicate a significant difference but because the data are nonnormally distributed we based our assessment of significant difference on the nonparametric test. All analyses were performed using SAS, version 9.4 (SAS Institute).

Results
Children With Strabismus
Ninety-one children with strabismus were included, of whom 45 (49.5%) were aged 0 to 4 years (median, 3 years), 31 (34.1%) were 5 to 11 years (median, 7 years), and 15 (16.5%) were 12 to 17 years (median, 14 years; Table). Demographics and clinical characteristics, by age group, are shown in the Table.

Overall, 44 of 91 children with strabismus (48.4%) had esotropia and 47 (51.6%) had exotropia (by age group in the Table). The median angle was 25 PD (range, 10-50 PD). Four children (4.4%) were unable to complete the child PedEyeQ and PedSQL questionnaires because of developmental delay, but all proxy and parent questionnaires were completed.

Visually Normal Controls
One hundred sixty-six children with normal visual acuity and no eye conditions were enrolled as a normal control group. Sixty-two of 166 (37.3%) were aged 0 to 4 (median, 2) years, 79 (47.6%) were aged 5 to 11 (median, 7) years, and 25 (15.1%) were 12 to 17 (median, 13) years.

Comparing PedEyeQ Scores in Children With Strabismus and Normal Controls
Child PedEyeQ
For children aged 5 to 11 years, child PedEyeQ scores were lower for children with strabismus compared with controls for all domains (Figure 1A; eTable 1 in the Supplement). For children aged 12 to 17 years, child PedEyeQ scores were also lower for children with strabismus compared with controls on all domains (Figure 1B; eTable 1 in the Supplement).

Proxy and Parent PedEyeQ
Proxy PedEyeQ scores for children aged 0 to 4 years were lower for children with strabismus compared with controls for all domains (Figure 2A; eTable 1 in the Supplement). When comparing proxy PedEyeQ scores for children aged 5 to 11 years and 12 to 17 years, all were lower for children with strabismus compared with controls (P < .001 for each; Figure 2 B and C; eTable 1 in the Supplement). For the parent PedEyeQ, all scores were lower for parents of children with strabismus compared with controls (Figure 3; eTable 1 in the Supplement).

Comparing PedEyeQ Scores in Children With Strabismus Alone and Normal Controls
Even though wearing eyeglasses, having amblyopia, and previous strabismus surgery might be considered integral com-
ponents of having strabismus, in children without these components, child 5- to 11-year PedEyeQ scores (7 [7.7%]; 6 with intermittent exotropia, 1 with constant exotropia) were lower compared with normal controls on all domains (Figure 4A; eTable 2 in the Supplement) except for the social domain (Figure 4A; eTable 2 in the Supplement). Proxy 5- to 11-year PedEyeQ scores (9 [9.9%]) were lower across all 5 domains for children with strabismus compared with controls (Figure 4B; eTable 2 in the Supplement). For the parent PedEyeQ, scores (9 [9.9%]) were also lower across all domains for parents of children with strabismus compared with parents of normal controls (Figure 4C; eTable 2 in the Supplement).

Comparing Generic PedsQL Scores in Children With Strabismus and Normal Controls
Across all child age groups, there were no differences between children with strabismus and normal controls in any PedsQL domain (eFigure 1A-C in the Supplement; eTable 3 in the Supplement) except for the physical functioning domain in children ages 13 to 17 years (eFigure 1C and eTable 3 in the Supplement). Across all proxy PedsQL modules and domains, there were no differences between children with strabismus and controls except in the school functioning domain for children ages 2 to 4 years (eFigure 1D-F and eTable 3 in the Supplement). For the PedsQL Family Impact Manual, scores were lower in several domains for parents of children with strabismus compared with controls, including emotional functioning, communication, worry, and daily activities domains (eFigure 2 and eTable 3 in the Supplement).

Discussion
Using the recently developed, child-derived PedEyeQ, we found that children with strabismus have poorer functional vision and ER-QOL than visually normal controls and their parents have a lower quality of life than parents of controls. General HRQOL, assessed using the PedsQL, was less affected, with
few differences between children with strabismus and normal controls.

The association of strabismus with quality of life in children has been evaluated in previous studies. Chai et al compared Hospital Anxiety and Depression Scale scores and National Eye Institute Visual Function Questionnaire-25 scores in children undergoing strabismus surgery and found more anxiety and depression and lower vision-related quality of life in children with strabismus compared with controls. Using the Intermittent Exotropia Questionnaire, scores were found to be lower for children with intermittent exotropia than for normal controls in 2 previous studies. The Adult Strabismus-20 questionnaire was also administered to children with intermittent exotropia, finding lower scores for children with strabismus than for controls. Kothari et al administered an 8-item quality-of-life questionnaire to children with strabismus and found significant negative psychosocial and emo-
tional associations. These previous findings are consistent with the findings of the present study in which we found lower functional vision and lower ER-QOL in children with strabismus and their families using the eye-specific PedEyeQ. The PedEyeQ has age-specific child and proxy versions, and the present study confirms that the PedEyeQ is sensitive to the specific concerns of children with strabismus and their parents.

The PedsQL general HRQOL questionnaire (parent-proxy version) was used in a previous study that found significantly lower scores in children with strabismus compared with controls without strabismus. In contrast, we found few differences between children with strabismus and normal controls using the Proxy PedsQL in the present study (only in the school functioning domain in children ages 2-4 years), but there are differences between our study and the previous study by Wen et al. that may explain discrepancies. Wen et al. had a much larger control group (n = 4097) than we had in the present study, so that despite the magnitude of differences between children with strabismus and controls being very small in their study (range, 3-5 points vs 0-15 points in the present study; eFigure 1 and eTable 3 in the Supplement), they were statistically significant. Our results are not inconsistent with these small differences because our 95% CIs were wide. It is important to consider clinically meaningful and statistically significant differences. In contrast to our finding with the proxy PedsQL, we found significant differences when using the proxy PedEyeQ, confirming our hypothesis that the new eye-specific PedEyeQ is more sensitive to the concerns of children with strabismus than the generic PedsQL.

We found that children with strabismus had lower functional vision scores than normal controls as reported by the children themselves and by the parents as proxy reporters (all ages; Figure 1; eTable 1 in the Supplement). The functional vision domain of the PedEyeQ contains questions regarding

**Figure 3. Parent Pediatric Eye Questionnaire (PedEyeQ) Domain Scores in Children With Strabismus and in Normal Controls**

Parent PedEyeQ domains include the impact on parent and family, worry about child’s eye condition, worry about child’s self-perception and interactions, and worry about child’s functional vision. The boxes represent first quartile, median, and third quartile values; whiskers represent extreme values.

**Figure 4. Pediatric Eye Questionnaire (PedEyeQ) Domain Scores in Children With Strabismus Without Current Amblyopia, Current Eyeglasses, or Previous Strabismus Surgery and in Normal Controls**

A, Child PedEyeQ scores for children ages 5 to 11 years (functional vision, bothered by eyes/vision, social, and frustration/worry). B, Proxy PedEyeQ scores for children ages 5 to 11 years (functional vision, bothered by eyes/vision, social, frustration/worry, and eye care). C, Parent PedEyeQ (impact on parent and family, worry about child’s eye condition, worry about child’s self-perception and interactions, and worry about child’s functional vision). The boxes represent first quartile, median, and third quartile values; whiskers represent extreme values.
difficulties in seeing, learning, concentrating, schoolwork, sports, and running into things (see https://public.jaeb.org/pedig/view/Other_Forms for full questionnaires). Other investigators have reported associated defects, such as poor binocular saccade coordination that may affect reading, postural deficits, problems with manual dexterity, and sensorimotor deficits. Nevertheless, the full spectrum of specific strabismus-associated functional deficits has not yet been fully characterized. The findings of the present study are important for confirming the presence of functional impairment in children with strabismus.

Eye-related quality of life was affected across domains for children with strabismus, including being bothered by their eyes, social concerns, frustration and/or worry regarding their eyes, and caring for their eyes. While previous studies have reported the general association of strabismus with psychosocial and emotional functioning or with vision- or eye-related quality of life, the present study provides a more granular evaluation of ER-QOL associations by using the child-derived, eye-specific PedEyeQ.

Using the parent component of the PedEyeQ, we found lower scores across all domains for parents of children with strabismus than for parents of normal controls (Figure 2C; eTable 1 in the Supplement). In addition, we found lower parental quality-of-life scores for some domains using the PedsQL Family Impact Module (eFigure 2 and eTable 3 in the Supplement). This finding is consistent with a previous study reporting lower HRQOL in parents of children with intermittent exotropia compared with parents of visually normal children. The domains of the parent PedEyeQ were identified from individual parent interviews and address specific worries associated with the child’s functional vision, their self-perception/interactions, the eye condition itself, and how the eye condition affects the family. While it may be expected that conditions such as strabismus would cause some parental concern, there may also be an element of poor understanding of the condition and its management. Eustis and Smith studied parental understanding of strabismus and strabismus surgery and found areas of substantial misinformation and uncertainty. It would be of interest to study the effectiveness of educational interventions on parental health-related quality of life.

Conclusions

Using the recently developed PedEyeQ, we found children with strabismus have impaired functional vision and reduced ER-QOL across distinct domains compared with normal controls. Parents of children with strabismus also experience a reduced quality of life. These findings help advance our understanding of the specific ways in which strabismus affects children and their families and are also helpful in identifying areas for future research. Using the PedEyeQ in children with strabismus may also reframe clinical management goals beyond motor and sensory outcomes.

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REFERENCES


