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Prevalence of strabismus, nystagmus and risk factors in children and adolescents born preterm with and without retinopathy of prematurity: results from the Gutenberg Prematurity Study Young

Achim Fieß ,[1] Sandra Gißler ,[1] Alica Hartmann ,[1] Eva Mildenberger,[2] Heike M Elflein ,[1] Omar Hahad,[3,4] Norbert Pfeiffer,[1] Stephanie D Grabitz,[1] Alexander K Schuster[1]

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[1]Department of Ophthalmology, University Medical Center of the Johannes Gutenberg University Mainz, Mainz, Germany
[2]Department of Pediatrics, University Medical Center of the Johannes Gutenberg University Mainz, Mainz, Germany
[3]Department of Cardiology, University Medical Center of the Johannes Gutenberg University Mainz, Mainz, Germany
[4]German Center for Cardiovascular Research, Mainz, Germany

Correspondence to
Prof. Achim Fieß;
achim.fiess@gmail.com

AF and SG are joint first authors. SDG and AKS are joint senior authors.

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ABSTRACT

Aims This study assessed the prevalence of strabismus, nystagmus and their risk factors in children born preterm, stratified by gestational age (GA), retinopathy of prematurity (ROP) and ROP treatment.

Methods This is a retrospective cohort study with a prospective follow-up in a large cohort of children born preterm and full-term aged 4–17 years. Multivariable logistic regression analyses assessed associations of strabismus and nystagmus with perinatal parameters. Participants were divided into the following groups: controls born at term (GA ≥37 weeks, group 1), children born preterm without ROP and GA 33–36 weeks (group 2), GA 29–32 weeks (group 3), GA ≤28 weeks (group 4), GA ≤32 weeks with untreated ROP (group 5) and GA ≤32 weeks with treated ROP (group 6).

Results 949 children (11.21±3.92 years, 495 females) were included. Strabismus was observed in 6% of children in group 1, 10% in group 2, 12% in group 3, 23% in group 4, 20% in group 5 and 68% in group 6. Nystagmus was observed in 0.8%, 0.4%, 1.8%, 2.6%, 5.0% and 47% in the respective groups. Strabismus was associated with earlier GA (OR=1.08; p=0.01), astigmatism (OR=2.48; p=0.02) and hypermetropia (OR=2.09; p=0.04). Esotropia was associated with weeks of prematurity (OR=1.11; p=0.02), anisometropia (OR=3.09; p=0.02) and hypermetropia (OR=4.17; p<0.001). Nystagmus was associated with ROP (OR=7.49; p=0.03), anisometropia (OR=5.17; p=0.04) and myopia (OR=11.09; p<0.001).

Conclusions Strabismus in children is linked to preterm birth and refractive error, while nystagmus is more prevalent in children with ROP and children with refractive errors.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Strabismus is a known complication of preterm birth, affecting visual quality of life. However, most studies are limited by small sample sizes, lack of detail on degrees of prematurity and retinopathy of prematurity (ROP) status and often exclude older children. While extremely preterm birth (≤28 weeks) is linked to strabismus, data on moderate to late preterm birth (28–36 weeks) and specific types like esotropia and exotropia remain limited.

WHAT THIS STUDY ADDS

⇒ This study highlights that prematurity—especially with ROP—is strongly linked to strabismus and nystagmus, with lower gestational age and refractive errors as key risk factors. Strabismus was more common in children with treated ROP but also increased with prematurity regardless of ROP.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings underscore that early diagnosis and regular ophthalmologic monitoring are essential not only for children with ROP but also for those born preterm without it—including those born moderately preterm—to avoid delays in amblyopia treatment and improve long-term visual outcomes.

INTRODUCTION

Preterm birth affects about 11% of the population worldwide[1] and leads to numerous ocular alterations during lifetime. While advancements in medical procedures in recent decades increased survival probability, especially of infants born extremely preterm,[2 3] ocular complications such as retinopathy of prematurity (ROP) remain and can lead to decreased visual function and blindness.[4] Further alterations in ocular morphology include a steeper corneal radius, shorter axial length and smaller anterior eye chambers,[5] which make individuals born preterm more prone to complications such as myopia, astigmatism, anisometropia and strabismus[6–10] and potentially increase the susceptibility for age-related ocular diseases.[11]

Strabismus is an ocular complication related to prematurity[12–14] and significantly impacts vision-related quality of life.[15] However, most studies assessing associations of strabismus and preterm birth are either performed in small cohorts of children[12] or do not differentiate between extremely

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(gestational age (GA) ≤28 weeks)[16] and moderately preterm birth (GA 32–37 weeks)[13 16] and occurrence of ROP and/or ROP treatment.[14 17] Most also do not include adolescents until the age of 17 years.[18 19] The consequences of strabismus reach from loss of binocular vision, amblyopia and reduced visual function[20] to psychosocial problems such as problems of finding employment or a partner.[21] Given the diverse consequences of strabismus, it is of particular importance to conduct a thorough examination of factors related to preterm birth and their potential impact on the development of strabismus. This may help with the identification of more precise intervention strategies during the perinatal period and more directed ophthalmological examination strategies during childhood, which may contribute to reducing the risk of strabismus and its sequelae, such as amblyopia, in this population. The goal of our current research effort was to assess the prevalence of strabismus and its subtypes (esotropia and exotropia) as well as the prevalence of nystagmus in a large cohort of children and adolescents aged 4–17 years, stratified for stages of preterm birth, ROP with and without treatment and the impact of factors related to prematurity. Additionally, we aimed to assess the age of first diagnosis in strabismic children with and without amblyopia to evaluate whether this had an impact in our cohort.

MATERIALS AND METHODS

Study population

The Gutenberg Prematurity Study Young (GPSY) is a retrospective cohort study with a prospective ophthalmologic examination in children aged 4–17 years, extending the Gutenberg Prematurity Eye Study for adults.[5 22] This study, which is conducted at the University Medical Centre of the Johannes Gutenberg University Mainz (UMCM) in Germany, focuses on a cohort of children and adolescents, aged 4–17 years, born either preterm or full-term between 2003 and 2018, to explore the impact of prematurity and associated factors. Most participants were Caucasian and therefore data cannot be generalised to other ethnicities. Perinatal data were collected retrospectively by reviewing medical records from the UMCM, while the prospective phase comprised extensive eye examinations.

The selection of participants was conducted via an algorithm that invited all individuals born preterm with a GA of ≤32 weeks and randomly selected one in three individuals born preterm with a GA of 33–36 weeks. This was prespecified to achieve comparable study group size and age and sex distribution. Controls were chosen by randomly selecting eight individuals born full-term (four male, four female) per month of birth, with a birth weight (BW) between the 10th and 90th percentile. Additionally, 30 participants born at term but severely small for GA (SGA), 30 participants born at term but moderately SGA, 30 individuals born at term but moderately large for GA (LGA) and 30 individuals born at term but severely LGA were recruited with stratification by sex and age. A detailed flow chart of the recruitment is displayed in online supplemental figure S1. The participants underwent examinations between 2021 and 2023 and provided additional information about their medical history through detailed surveys.

We obtained written informed consent from all participants and their legal guardians before enrolment. The GPSY adheres to Good Clinical Practice, Good Epidemiological Practice and the ethical guidelines of the Declaration of Helsinki. The study protocol and documentation were approved by the local ethics committee of the Medical Chamber of Rhineland-Palatinate, Germany (reference no. 2021–15830; original approval: 5 May 2021; most recent update: 19 January 2022).

Assessment of prenatal, perinatal and postnatal medical history

Medical records at the UMCM were examined for various data points, including GA (in weeks), BW (in kg), presence and stage of ROP, ROP treatment, placental insufficiency, pre-eclampsia, breastfeeding status, maternal smoking during pregnancy, maternal gestational diabetes, maternal age at birth, caesarean section and any perinatal adverse events, defined according to the German query for quality control of the neonatal clinics: occurrence of intraventricular haemorrhage (at least grade three or parenchymal haemorrhage) and/or the occurrence of necrotising enterocolitis and/or moderate or severe bronchopulmonary dysplasia were summarised as adverse events.[23] BW percentiles were calculated based on the methodologies established by Voigt *et al*.[24]

Categorisation

Participants were divided into six groups based on GA and the presence of ROP. Group 1 included term-born children with a GA at birth of 37 completed weeks or more. Group 2 comprised participants born preterm with a GA of 33–36 weeks who did not have ROP. Group 3 consisted of those with a GA of 29–32 weeks without ROP, while group 4 included participants with a GA ≤28 weeks, also without ROP. Group 5 was made up of participants with a GA of ≤32 weeks and non-treated ROP, and group 6 included those with a GA of ≤32 weeks and treated ROP. If only one eye was affected by ROP, the unaffected eye was excluded from the analysis. Of the treated participants within our study, only one participant received intravitreal operative medication and one participant received both cryo and laser treatment, while all other participants underwent laser treatment.

Ophthalmological examination

Participants underwent a detailed ophthalmological examination, including testing of monocular visual acuity without correction and distant corrected visual acuity with ARK 1s (NIDEK; Oculus, Wetzlar, Germany) and testing of the intraocular pressure with a non-contact tonometer (NT 2000; Nidek, Japan). Visual acuity was converted from decimal to logMAR, according to medical literature.[25] An orthoptic examination for strabismus was conducted, including the cover–uncover test and alternate cover test, Hirschberg test and examination of fixation behaviour. Ocular movements were assessed, and stereopsis was tested with the Lang-II test. After correction for refractive error, the presence or absence of nystagmus was investigated. Strabismus was defined as constant or intermittent heterotropia of any dimension at distance and/or near fixation after having corrected refractive error.[26] Additionally, we categorised depending on the deviation from the primary position (esotropia, exotropia). The spherical equivalent was calculated by summing the sphere value with half of the cylindrical value. Anisometropia was determined by calculating the absolute difference in spherical equivalent between the right and left eyes. Anisoastigmatism was assessed by measuring the absolute difference in cylindrical values between the two eyes. Amblyopia was defined according to Elflein *et al*[27] and assessed to explore whether the age of first diagnosis in strabismic children had an impact on the development of amblyopia. For further details regarding amblyopia in this cohort, we refer to Fieß *et al*.[28] Investigators were masked regarding the GA and BW of the participants.

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Covariates

The risk factors that may affect the outcome measures such as sex (female), age (years), weeks of prematurity (40—GA in weeks), BW percentile, ROP (yes), ROP treatment (yes), anisometropia ≥1.5 diopter (D) (yes), refractive error: myopia ≤−2 D and hyperopia ≥+2 D (reference: −2 to 2 diopter), astigmatism ≥1.5 D (yes), maternal age at childbirth (years), maternal smoking during pregnancy (yes), maternal breastfeeding (yes), perinatal adverse events (yes), pre-eclampsia (yes), placental insufficiency (yes) and caesarean section (yes) were considered as covariables.

Statistical analysis

The primary outcome measure was the presence of any type of strabismus during the study examination. Secondary outcomes included the presence of specific strabismus subtypes (esotropia, exotropia) as well as nystagmus. Descriptive statistics were presented by group of prematurity, reporting absolute and relative frequencies for binary variables, and mean with SD for variables that were approximately normally distributed (otherwise median and IQR). Associations between strabismus (yes) and prematurity-related factors were assessed by binary logistic regression analysis.

First, univariable analyses were conducted investigating the relationship with weeks of prematurity (40—GA in weeks), BW (kg), BW percentile, ROP, ROP treatment, placental insufficiency, pre-eclampsia, maternal smoking during pregnancy, perinatal adverse events and breastfeeding. To identify independently associated factors, a multivariable regression model #1 was applied with the inclusion of the factors described above that were associated with a p value <0.05 in the univariable analysis. We additionally conducted a sensitivity analysis of the univariable association of ROP stages and strabismus.

Additionally, we created a cumulative incidence plot with retrospective anamnestic data of first diagnosis of strabismus to estimate onset probabilities over time in our study population (see figure 1).

We further conducted a sensitivity analysis with a permutation test regarding the age of first diagnosis in strabismic children with and without amblyopia to assess whether this had an impact in our cohort.

As this is an explorative study, a significance level was not defined, and no adjustment for multiple testing was conducted. Thus, p values are reported only for descriptive purposes and should be interpreted with caution.[29] Instead, ORs with their corresponding CIs can be used to assess the effects. Calculations were performed using R (R Core Team (2021); R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, URL https://www.R-project.org/, R V.4.1.2 (1 November 2021)).

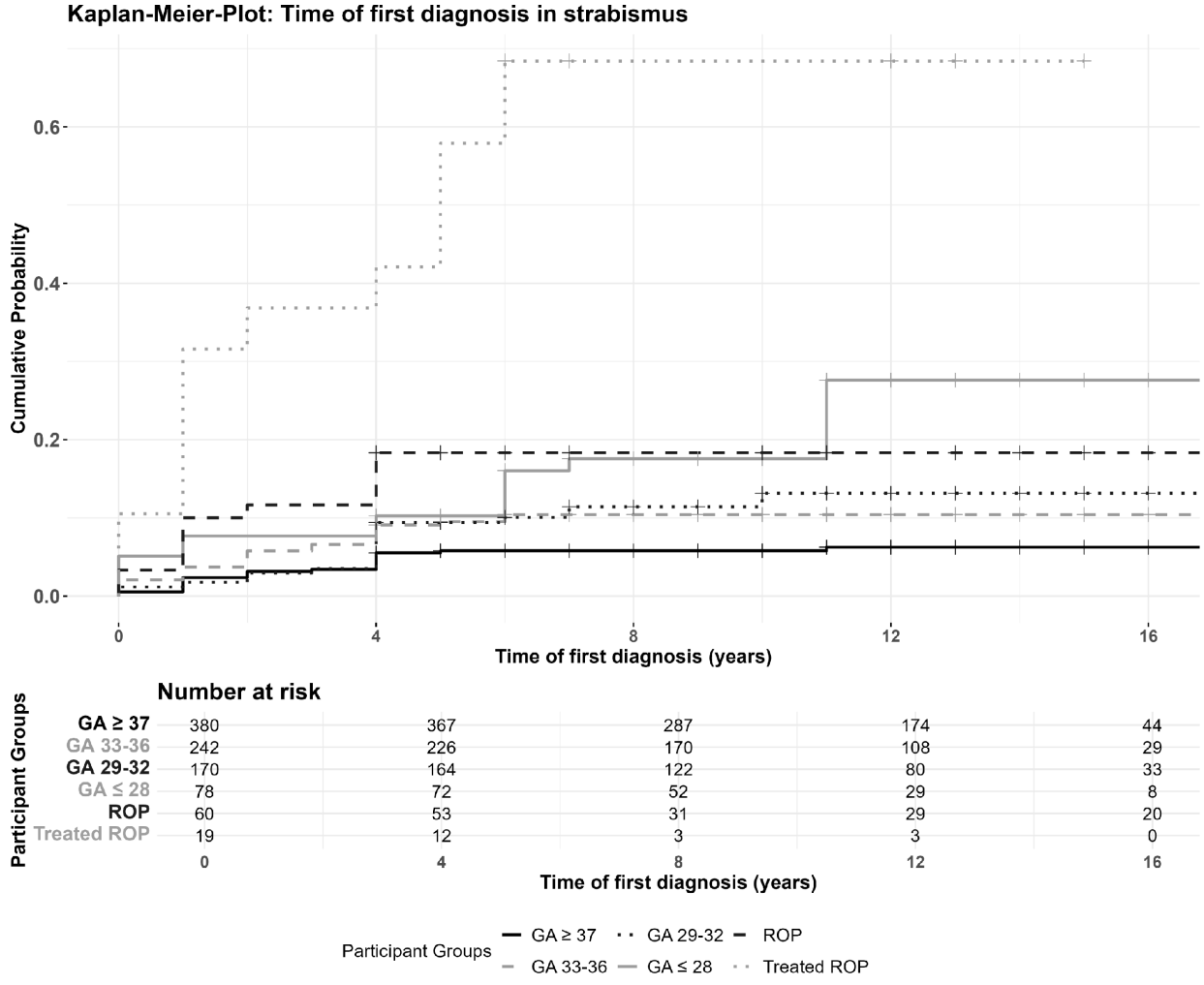

Figure 1 Cumulative incidence of first diagnosis of strabismus within participant groups gathered from retrospective anamnestic data of strabismus onset. GA, gestational age in weeks; ROP, retinopathy of prematurity

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Table 1 Characteristics of the GPSY sample (n=949), stratified by study groups

	Group 1 GA ≥37 wks	Group 2 GA 33–36 wks No ROP	Group 3 GA 29–32 wks No ROP	Group 4 GA ≤28 wks No ROP	Group 5 GA ≤32 wks ROP without treatment	Group 6 GA ≤32 wks ROP with treatment
Participants (n)	380	242	170	78	60	19
Sex (female)	195 (51.3)	120 (49.6)	90 (52.9)	47 (60.3)	34 (56.7)	9 (47.4)
Age, y (mean (SD))	11.04 (3.72)	11.17 (3.75)	11.69 (3.93)	10.79 (3.94)	11.93 (5.39)	10.47 (4.30)
Gestational age (weeks) (mean (SD))	38.98 (1.29)	34.64 (1.04)	30.89 (1.05)	26.17 (1.45)	26.43 (2.35)	24.05 (1.08)
Birth weight, kg (mean (SD))	3.38 (0.64)	2.33 (0.41)	1.57 (0.35)	0.85 (0.25)	0.93 (0.35)	0.62 (0.20)
Birth weight <1500 g (yes) (%)	1 (0.3)	7 (2.9)	74 (43.5)	78 (100.0)	57 (95.0)	19 (100.0)
Birth weight <1000 g (yes) (%)	0 (0.0)	0 (0.0)	10 (5.9)	58 (74.4)	40 (66.7)	18 (94.7)
Birthweight percentile (mean (SD))	46.24 (33.40)	33.98 (22.83)	40.47 (22.37)	36.79 (26.11)	42.23 (27.11)	22.95 (24.26)
Birthweight percentile categories n (%)						
<3rd percentile	30 (7.9)	11 (4.5)	5 (2.9)	7 (9.0)	1 (1.7)	3 (15.8)
3rd –<10th percentile	30 (7.9)	31 (12.8)	11 (6.5)	7 (9.0)	9 (15.0)	4 (21.1)
10th–90th percentile	260 (68.4)	197 (81.4)	154 (90.6)	62 (79.5)	50 (83.3)	12 (63.2)
>90th–97th percentile	30 (7.9)	2 (0.8)	0 (0.0)	2 (2.6)	0 (0.0)	0 (0.0)
>97th percentile	30 (7.9)	1 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
ROP (yes) (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	60 (100.0)	19 (100.0)
ROP stage (1/2/3/4/5) OD (eyes)	(0/0/0/0/0)	(0/0/0/0/0)	(0/0/0/0/0)	(0/0/0/0/0)	(27/15/14/0/0)	(0/2/14/2/1)
ROP stage (1/2/3/4/5) OS (eyes)	(0/0/0/0/0)	(0/0/0/0/0)	(0/0/0/0/0)	(0/0/0/0/0)	(22/19/17/0/0)	(0/1/12/2/1)
Perinatal adverse events (yes) (%)	0 (0.0)	1 (0.4)	7 (4.1)	32 (41.0)	26 (43.3)	18 (94.7)
Pre-eclampsia (yes) (%)	7 (1.8)	21 (8.7)	30 (17.6)	12 (15.4)	12 (20.0)	2 (10.5)
Placental insufficiency (yes) (%)	2 (0.5)	8 (3.3)	6 (3.5)	6 (7.7)	3 (5.0)	2 (10.5)
Gestational diabetes (%)	46 (12.1)	19 (7.9)	21 (12.4)	3 (3.8)	4 (6.7)	0 (0.0)
Maternal smoking during pregnancy (yes) (%)	17 (4.5)	7 (2.9)	7 (4.1)	5 (6.4)	8 (13.3)	4 (21.1)
Breastfeeding (yes) (%)	322 (84.7)	183 (75.6)	119 (70.0)	53 (67.9)	28 (46.7)	2 (10.5)
Maternal age at birth (years) (mean (SD))	32.96 (4.21)	33.57 (4.82)	32.88 (4.70)	32.23 (5.49)	33.88 (3.99)	31.59 (3.24)
Caesarean section (yes) (%)	147 (38.7)	148 (61.2)	140 (82.4)	74 (94.9)	53 (88.3)	14 (73.7)
Lang II-Test positive (yes) (%)	8 (2.1)	6 (2.5)	8 (4.7)	7 (9.0)	5 (8.3)	13 (68.4)
Amblyopia overall (yes) (%)	11 (2.9)	12 (5.0)	8 (4.7)	7 (9.0)	3 (5.0)	8 (42.1)

*Perinatal adverse events were defined as the occurrence of intraventricular haemorrhage (at least grade three or parenchymal haemorrhage) and/or the occurrence of necrotising enterocolitis and/or bronchopulmonary dysplasia (moderate or severe).
g, grams; GA, gestational age; kg, kilograms; n, number; OD, right eye; OS, left eye; ROP, retinopathy of prematurity; SD, Standard Deviation; wks, weeks; y, years.

RESULTS

Study participants' characteristics

A total of 1889 eyes of 949 preterm and term infants (age 11.21±3.92 years, 495 females) were included in the analysis. Overall, 760 eyes of 380 participants with a GA ≥37 weeks (group 1, control group), 484 eyes of 242 participants with a GA between 33 and 36 weeks without ROP (group 2), 340 eyes of 170 participants with a GA between 29 and 32 weeks without ROP (group 3), 156 eyes of 78 participants with a GA ≤28 weeks without ROP (group 4), 114 eyes of 60 participants with a GA between 24 and 32 weeks with ROP without treatment (group 5) and 35 eyes of 19 participants with a GA between 24 and 32 weeks and with postnatal treatment for ROP (group 6) were assessed. Nine eyes without ROP were excluded when the fellow eye had postnatal ROP. The group characteristics are displayed in table 1.

Ocular parameters

Descriptive parameters regarding strabismus, nystagmus and visual acuity are displayed in figure 2a–f.

Strabismus

In the descriptive analysis, strabismus was observed in 6.1% of participants with a GA of ≥37 weeks, 10.3% of participants with a GA of 33–36 weeks, 12.4% of participants with a GA of 29–32 weeks, 23.1% of participants with a GA of ≤28 weeks without ROP, 20.0% of participants with untreated ROP and 68.4% of participants with treated ROP. Considering a potential impact of age, our data show that the prevalence of strabismus was similar within the different age groups. Preschool children aged 4–6 years, school children aged 7–12 years as well as adolescents aged 13–17 years all had similar prevalences of strabismus stratified over the different groups of prematurity except for the children with ROP (see figure 2a). The exceptionally high prevalence in the children with ROP without treatment aged 7–12 years (three of six participants, 50%) is likely attributed to a lower participant number in this group within the participants with ROP. Results regarding the association analyses with strabismus are displayed in table 2. In multivariable regression, strabismus was associated with weeks of prematurity (OR=1.08; 95% CI 1.02; 1.16; p=0.01), astigmatism ≥1.5 dioptres (OR=2.48; 95% CI 1.15; 5.14; p=0.02) and hypermetropia (OR=2.09; 95% CI 1.01; 4.07; p=0.04). In a sensitivity analysis, we used a univariable model to assess the association of ROP stage with strabismus. Only the second (OR=3.46; 95% CI 1.09; 9.42; p=0.02) and third (OR=12.0; 95% CI 5.53; 26.74; p<0.001) stages were associated with strabismus; however, we were not able to assess this association in a multivariable model due to the small case numbers, especially in the higher stages. Figure 2c displays the distribution of strabismus in cases with and without treatment over the different stages of ROP.

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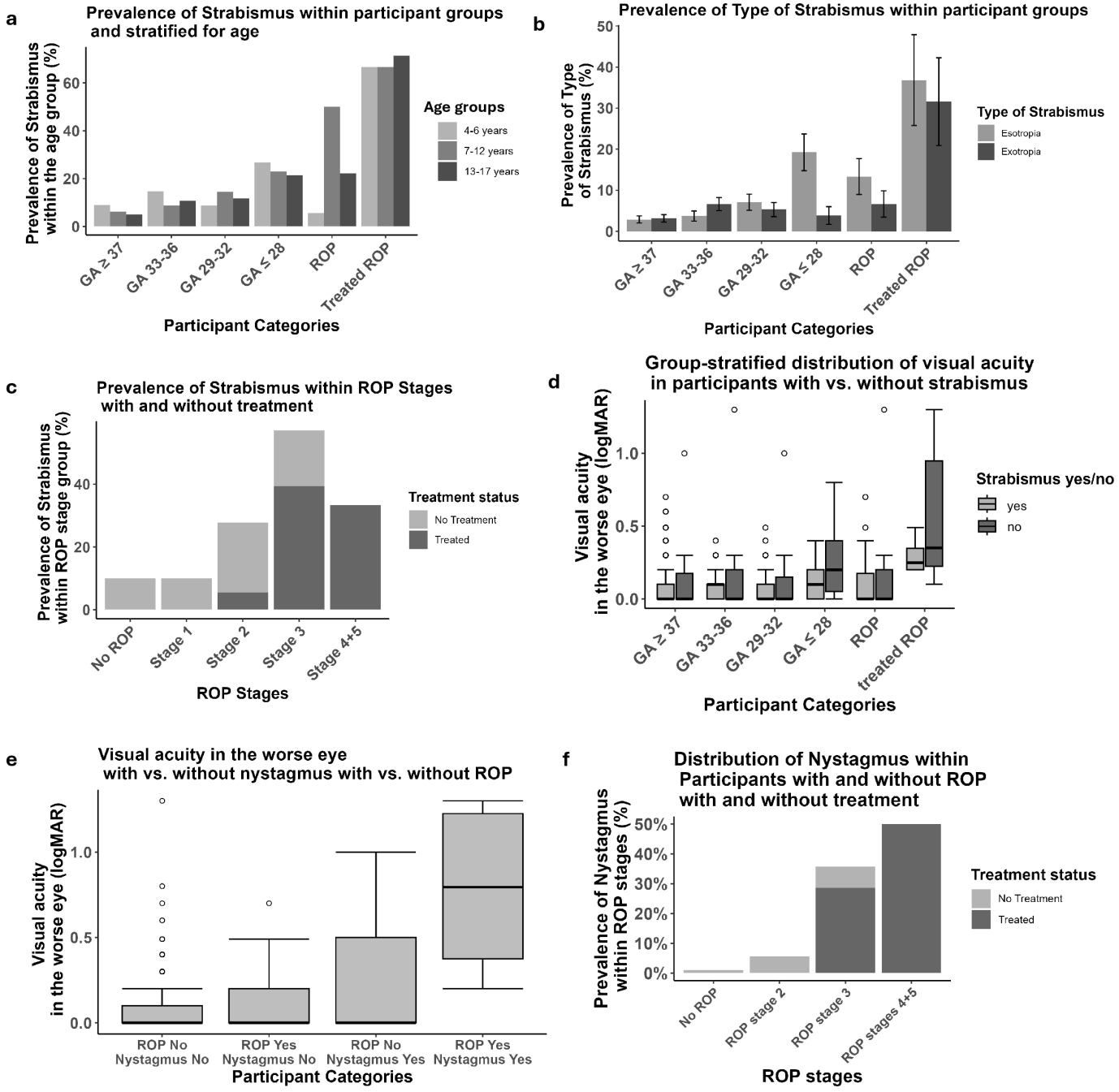

Figure 2 Graphical display of the prevalences of strabismus and nystagmus within participant groups and distribution of visual acuity in participants with and without nystagmus and strabismus. (a) Graphical display of the prevalence of strabismus within participant groups stratified for age group, (b) graphical display of the types of strabismus within participant groups, (c) prevalence of strabismus within ROP stages with and without treatment, (d) group-stratified distribution of visual acuity in participants with versus without strabismus, (e) visual acuity in the worse eye with versus without nystagmus with versus without ROP, (f) distribution of nystagmus within participants with and without ROP with and without treatment; GA, gestational age in weeks; ROP, retinopathy of prematurity.

Prevalences of esotropia were 2.9%, 3.7%, 7.1%, 19.2%, 13.4% and 36.8% in the respective groups, while they were 3.2%, 6.6%, 5.3%, 3.8%, 6.7% and 31.6% for exotropia.

Esotropia was associated with weeks of prematurity (OR=1.11; 95% CI 1.02; 1.21; p=0.02), anisometropia ≥1.5 dioptres (OR=3.09; 95% CI 1.18; 7.58; p=0.02) and hypermetropia ≥2 dioptres (OR=4.17; 95% CI 1.83; 8.99; p<0.001). Exotropia was only associated with pre-eclampsia (OR=2.57; 95% CI 1.17; 5.25; p=0.01). Further results regarding association analyses with esotropia, exotropia and nystagmus can be found in online supplemental table S1.

Nystagmus

In descriptive analyses, nystagmus was present in 0.8% of participants with a GA of ≥37 weeks, 0.4% of participants with a GA of 33–36 weeks, 1.8% of participants with a GA of 29–32 weeks, 2.6% of participants with a GA of ≤28 weeks without ROP, 5.0% of participants with untreated ROP and 47.4% of

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Table 2 Stratified participant characteristics and association analyses of strabismus

Strabismus	No strabismus	Strabismus	Univariable		Model 1	
Logistic regression			OR (95% CI)	P value	OR (95% CI)	P value
n	837	112				
Age (years)	11.19 (3.90)	11.39 (4.11)	1.01 (0.96; 1.07)	0.61	–	–
Sex (female)	437 (52.2)	58 (51.8)	0.98 (0.66; 1.46)	0.93	–	–
Weeks of prematurity (40—GA)	Mean GA=34.69 (4.65)	Mean GA=31.22 (5.61)	1.15 (1.1; 1.19)	<0.001	1.08 (1.02; 1.16)	0.01
Birth weight percentile	40.90 (28.40)	38.21 (29.12)	1.00 (0.99; 1.00)	0.35	–	–
ROP (yes)	54 (6.5)	25 (22.3)	4.17 (2.44; 6.97)	<0.001	1.25 (0.57; 2.71)	0.57
ROP treatment (yes)	6 (0.7)	13 (11.6)	18.19 (7.02; 52.76)	<0.001	*	*
Perinatal adverse events (yes)	53 (6.3)	31 (27.7)	5.66 (3.41; 9.29)	<0.001	1.32 (0.6; 2.87)	0.48
Smoking during pregnancy (yes)	37 (4.4)	11 (9.8)	2.35 (1.11; 4.62)	0.02	1.25 (0.48; 2.9)	0.63
Pre-eclampsia (yes)	63 (7.5)	21 (18.8)	2.84 (1.62; 4.8)	<0.001	1.89 (0.99; 3.48)	0.05
Breastfeeding (yes)	635 (75.9)	72 (64.3)	0.57 (0.38; 0.88)	0.01	0.93 (0.56; 1.57)	0.77
Placental insufficiency (yes)	19 (2.3)	8 (7.1)	3.31 (1.34; 7.51)	0.01	1.94 (0.69; 4.95)	0.19
Anisometropia ≥1.5 D (yes)	24 (2.9)	14 (14.0)	5.37 (2.62; 10.64)	<0.001	2.30 (0.97; 5.20)	0.05
Astigmatism ≥1.5 D (yes)	32 (3.9)	20 (19.6)	6.0 (3.24; 10.9)	<0.001	2.48 (1.15; 5.14)	0.02
Myopia ≥2 D (yes)	49 (6.0)	13 (12.7)	3.53 (1.86; 6.45)	<0.001	1.78 (0.8; 3.72)	0.14
Hyperopia ≥2 D (yes)	48 (5.9)	13 (12.7)	2.99 (1.56; 5.48)	<0.001	2.09 (1.01; 4.07)	0.04
Maternal age at birth (years)	33.15 (4.58)	32.55 (4.27)	0.97 (0.93; 1.02)	0.22	–	–
Caesarean section (yes) (%)	496 (59.3)	80 (71.4)	1.72 (1.13; 2.68)	0.01	0.84 (0.49; 1.46)	0.53
Lang II-Test positive (yes)	14 (1.7)	33 (29.5)	–	–	–	–
Nystagmus (yes)	4 (0.5)	17 (15.5)	–	–	–	–

Univariable model—based on univariable logistic regression analysis; model 1: multivariable model with inclusion of univariable associated parameters.
*ROP treatment, although associated with weeks of prematurity, was not included in the multivariable model due to high collinearity with ROP.
CI, confidence interval; D, diopters; GA, gestational age; OR, odds ratio; ROP, retinopathy of prematurity.

participants with treated ROP. The strongest factors associated with nystagmus in multivariable analysis were the occurrence of ROP (OR=7.49; 95% CI 1.31; 49.99; p=0.03), anisometropia ≥1.5 dioptres (OR=5.17; 95% CI 1.00; 24.59; p=0.04) and myopia ≥2 dioptres (OR=11.09; 95% CI 2.61; 48.20, p<0.001). The nystagmus in these participants was largely characterised by low amplitudes and high frequency. There were some individuals who had nystagmus but not strabismus, but these cases were rare (four individuals overall, 0.5%). Of these, two were from the group with term-born individuals, one in the group with a GA of 33–36 weeks and one from the group with GA ≤28 weeks.

The cumulative incidence of strabismus (figure 1) gathered from a review of medical data in the eye clinic and retrospective anamnestic data clearly shows that strabismus in our cohort is diagnosed particularly within the first years of life. Furthermore, the groups treated for ROP had the overall highest cumulative incidence of strabismus compared with the other groups, while children born at term had the lowest. The sensitivity analysis regarding amblyopia did not reveal a difference (p=0.98) in the mean age of first diagnosis between strabismic children with and without amblyopia in our cohort. Within the individuals with strabismus, amblyopia was most prevalent in participants with esotropia (44.2%) compared with the ones with exotropia (31.6%). Of the individuals without a diagnosis of strabismus, 2.2% were amblyopic.

DISCUSSION

This study provides a detailed assessment of the association of perinatal parameters with strabismus prevalence in a large cohort of 949 children and adolescents aged 4–17 years. Prevalence of strabismus and nystagmus was highest in children born preterm with treated ROP. We found an association of strabismus with weeks of prematurity, astigmatism ≥1.5 dioptres and hypermetropia ≥2 dioptres, while the strongest factors associated with nystagmus were the occurrence of myopia ≥2 dioptres, ROP and anisometropia ≥1.5 dioptres. Esotropia was associated with weeks of prematurity, anisometropia ≥1.5 dioptres and hypermetropia ≥2 dioptres, while exotropia was only associated with pre-eclampsia. Our results indicate an 8% increase in the odds of having strabismus with each week of birth before the full gestation of 40 weeks, independent of the occurrence of ROP and/or ROP treatment.

This study was particularly interested in determining whether fetal growth restriction or preterm birth plays a more important role in the prevalence of strabismus. We found no association of BW percentile and strabismus, while GA played a major role in the multivariable association with inclusion of known risk factors such as anisometropia or anisoastigmatism. These results stand out compared with previous studies in this field by considering the BW percentile instead of GA and BW as separate characteristics.[6 12 13 30] BW should always be considered in relation to GA, as children with the same BW but one born at term and the other born preterm may have very different outcomes. Our study suggests that it is neonatal immaturity that plays a decisive role in the development of strabismus, rather than adverse fetal growth indicated by a low-birth-weight percentile.

Of the 59 preterm children in Pettursdottir *et al*'s analysis, 7 (11.9%) were strabismic, of which five had no ROP and two had treated ROP. The authors, however, did not differentiate between the severity of preterm birth but only used a dichotomous model.[12] VanderVeen *et al* found an association of strabismus with preterm birth before 26 weeks and ROP type I, which they defined as ROP in need of treatment. While VanderVeen *et al* have incorporated some form of severity of preterm birth and ROP and its treatment, they only focused on extremely preterm

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children up to a GA of 28 weeks.[13] Fieß *et al* have found that GA was associated with strabismus, although they have also only assessed children below 32 weeks of GA in their analysis of children aged 4–10 years.[26] Our stratification approach allowed us to differentiate strabismus prevalence regarding different severities of preterm birth (including children born moderately and late preterm) between children born preterm without ROP and children with ROP and/or ROP treatment. Regarding the strabismus prevalences in the different groups of prematurity independent of ROP, an increase in prevalence is clearly visible with a decrease in GA, which is manifested by the association between weeks of GA and strabismus in our multivariable model and is in line with results from previous studies.[26 31] Still, prevalences in our cohort were highest in the group treated for ROP, which was the same for all age groups. Our univariable sensitivity analysis showed that mainly ROP stages 2 and 3 are associated with strabismus. The group with stage 3 ROP had 12 times the odds of strabismus compared with children without ROP. These results are also visualised in figure 2c and are in line with results from Chapron *et al*, who have found a significant association of strabismus with severe stages of ROP, which was defined as ROP stage ≥3 or treated ROP.[31] Within stage 3 ROP, about two-thirds of participants in our study were treated with laser therapy, while the rest received no treatment. It is therefore reasonable that mainly interventions such as laser therapy may alter the ocular architecture in ways that impact the coordination of eye movements. The missing association in the higher stages, in which all participants were treated (see figure 2c), is very likely attributed to the small numbers of participants and loss of power. As Chapron *et al* combined stages ≥3 or treated ROP, they were also not able to differentiate between treatment and higher stages of ROP without treatment.[31]

The current study also assessed the prevalence of esotropia and exotropia. Esotropia was the most prevalent type overall in our cohort. Interestingly, the difference in prevalence between esotropia and exotropia was highest in children with a GA ≤28 weeks. There may be underlying factors that affect brain development in these children.[32] Periventricular leukomalacia (PVL) has been described as a major factor contributing to the development of strabismus[33] and is mainly present in extremely to moderately preterm children, as its prevalence increases with decreasing GA.[34] Further, white matter damage has also been described as a contributing factor for strabismus,[35] and punctual white matter damage is also prevalent in children born moderately to late preterm.[36] A case report has further reported that in seven children with newly developed strabismus, six had a history of preterm birth and newly found signs of PVL, which were not seen before, even without any further neurological problems.[37] A hypothesis is therefore that mechanisms such as PVL, as seen in extremely preterms and diffuse white matter change in moderately to late preterms, increase the prevalence of strabismus. Whether the type of brain alteration also has certain effects on the type of strabismus that then occurs is still an object of ongoing research. This may, however, be of relevance, as differences between the outcomes of the two types have been described, not only regarding amblyopia prevalence[30 32] but also regarding differences in the success of surgical outcomes.[38] In individuals with ROP treatment, however, the impact of the disease and treatment of the retina might influence this development[39] and lead to a larger overall prevalence of amblyopia in this population.[28] However, further studies are needed to evaluate these hypotheses. Our findings regarding an association of pre-eclampsia and exotropia have similarly been found in a previous study that has assessed maternal hypertensive disorders in pregnancy,[40] suggesting that it might be necessary to screen children born to mothers with maternal hypertensive disorders and pre-eclampsia more intensively regarding the development of strabismus.

Strabismus in childhood can have different ages of onset depending on its type. Infantile strabismus typically develops within the first months after birth, while accommodative strabismus, often linked to refractive errors like hyperopia, tends to appear later.[41] In our cohort, strabismus was generally diagnosed before age 5, with the earliest diagnoses in children with ROP (median: 1 year). In contrast, children born moderately or extremely preterm were often diagnosed later (median: 3–4 years). This pattern may reflect both delayed detection, perhaps due to challenges in examining neurologically immature children, potentially caused by differences in neurodevelopment[42] and genuine differences in onset, particularly with accommodative types, which usually emerge later.[41]

Although our anamnestic data did not allow us to distinguish between infantile and accommodative types or between true onset and diagnosis, the later diagnosis in moderately preterm children, combined with their known higher risk for refractive errors,[6–10] supports the hypothesis that accommodative strabismus may be more prevalent in this group.

Current German guidelines recommend ophthalmologic follow-up only for children born before 31+0 weeks of GA or with BW <1500 g,[43] leaving many moderately to late preterm children unscreened, despite their potential risk. If these children developed strabismus earlier, especially infantile types, delayed diagnosis could mean missed opportunities for timely amblyopia treatment, although not all children with strabismus necessarily develop amblyopia. However, in our sample and sensitivity analysis, age at diagnosis did not significantly differ between children with and without amblyopia, suggesting that most were diagnosed early enough for intervention. Overall, amblyopia was more prevalent in the individuals with esotropia compared with exotropia, which is in line with a previous study by Yetkin *et al*.[30] This may be due to intermittent forms of exotropia, which result in amblyopia less than in constant forms.[44]

These findings underscore the importance of routine ophthalmologic follow-up in all preterm children, not just those with ROP or very low BW, ideally extending through at least 5 years of age.

Regarding the assessment of nystagmus, the prevalence was highest in the group with ROP treatment (47.7 %). In a Danish study, the prevalence of infantile nystagmus was highest in children born extremely preterm, with ROP being the leading cause.[45] However, the authors did not stratify for ROP and ROP treatment. Our results can stratify for this, and they show that, while GA was not associated with nystagmus, ROP was. Nevertheless, the prevalence was highest in the group with ROP treatment. Additionally, while children with stage 1 ROP did not have nystagmus and the prevalence in stage 2 was negligible, the prevalence rose with higher stages of ROP, in which most participants underwent treatment (see figure 2f), indicating that ROP treatment is responsible for the higher prevalence of nystagmus in children born extremely preterm. The association of nystagmus with refractive errors found in our multivariable model is therefore rather a result of ROP treatment than a driving factor behind nystagmus development. Our participants mostly exhibited nystagmus with low amplitudes and high frequency, which according to Brodsky *et al* is mainly observed in individuals with white matter damage.[46] As nystagmus has been described in combination with white matter injury[47] and children with treated ROP often have a higher risk of abnormalities

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in their brain structure,[48] this may be the underlying reason for the difference in the prevalences. Additionally, nystagmus seems to increase the risk for abnormal visual function[49] and may be one of the contributing reasons for the decrease in visual acuity. This is in accordance with our study, where visual acuity was worse in participants with nystagmus compared with the ones without, even in the cases without ROP, while it was the worst in children with nystagmus and ROP (see figure 2e). The association with refractive errors in our cohort is supportive of these findings as well.

Strengths and limitations

The GPSY was conducted in a single hospital study design, which limits our results regarding the applicability to the whole population. A portion of potential participants declined participation or was difficult to contact, contributing to possible selection bias. Individuals with greater morbidity may have been under-represented, potentially skewing the results towards those with less severe conditions. Furthermore, the study included only a small number of participants with advanced stages of ROP and ROP treatment, potentially affecting the generalisability of long-term outcomes. Most participants were Caucasian, limiting the applicability of results to other ethnic groups. Additionally, factors such as family history of refractive error, cerebral lesions and cognitive delay could not be fully adjusted for, which may influence the reported outcomes. We were not able to assess differences between recruited and non-recruited participants, as only recruited participants were added to the database. Due to the substantial imbalance in group sizes and the number of covariates considered, there is a risk of unstable coefficient estimates. These results should be interpreted with caution, and future studies with larger balanced samples are needed to confirm these findings. Previous studies have also found an association of strabismus with a family history of strabismus.[50] Family history of nystagmus was not collected, and as the response rate from the parents of our participants was rather low regarding family history of strabismus, we were not able to include this variable in our models, which further limits our interpretations. Anamnestic data regarding the first diagnosis of strabismus were only collected dichotomously and did not entail whether the type was exotropia or esotropia.

Despite these limitations, this study stands out for examining one of the largest cohorts of individuals born preterm during childhood, stratified into extremely, moderately and late preterm birth as well as with and without ROP and/or treatment and including a term-born control group. It bridges the gap between former studies spanning ages from 4 to 17 years. By not only assessing strabismus but also esotropia and exotropia separately, it has provided new information regarding a potential effect of low GA on esotropia rather than exotropia, which may pave the way for new insights into the development of strabismus and nystagmus. The comprehensive data gathered from perinatal records enabled a robust analysis of factors influencing these outcomes, with visual assessments conducted by masked investigators, minimising investigator bias. All examinations followed strict standardised protocols, enhancing the reliability of the findings and providing a clear view of the associations between prematurity, ROP and long-term visual outcomes.

CONCLUSIONS

In conclusion, this study offers insights into the relationship between perinatal factors and the prevalence of strabismus and nystagmus in a large cohort of children and adolescents. Our findings highlight that prematurity, particularly in cases involving ROP, plays a significant role in the development of strabismus, with the strongest associations observed with lower GA and refractive errors, such as anisometropia and astigmatism. The study also underscores the importance of distinguishing between children born preterm with and without ROP, as the prevalence of strabismus and nystagmus was notably higher in those with ROP, particularly those who received treatment. As prevalences of strabismus, however, increased with GA irrespective of ROP, this suggests that early diagnosis and consistent ophthalmologic monitoring are also crucial for children born preterm without ROP, even in children born moderately preterm, to prevent delayed amblyopia treatment and optimise visual outcomes.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants. The study protocol and documentation were approved by the local ethics committee of the Medical Chamber of Rhineland-Palatinate, Germany (reference no. 2021-15830; original approval: 5 May 2021; most recent update: 19 January 2022). Participants gave informed consent to participate in the study before taking part.

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Data availability statement Data are available upon reasonable request. AF had full access to all study data and takes responsibility for the integrity of the data and the accuracy of the data analysis. Statistical analyses were performed by AF and SaG. The analysis presents clinical data of a cohort. This project constitutes a major scientific effort with high methodological standards and detailed guidelines for analysis and publication to ensure scientific analyses are on the highest level. Therefore, data are not made available for the scientific community outside the established and controlled workflows and algorithms. To meet the general idea of verification and reproducibility of scientific findings, we offer access to data at the local database upon request at any time. Interested researchers may make their requests to the coordinating principal investigator of the GPES (Achim Fieß; achim.fiess@unimedizin-mainz.de). More detailed contact information is available at the homepages of the University Medical Center Mainz (www.unimedizin-mainz.de).

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ORCID iDs
Achim Fieß http://orcid.org/0000-0002-3867-2350
Sandra Gißler http://orcid.org/0000-0001-6052-3987
Alica Hartmann http://orcid.org/0000-0002-8721-6036
Heike M Elflein http://orcid.org/0000-0003-4630-6438

REFERENCES

1 Chawanpaiboon S, Vogel JP, Moller A-B, *et al*. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *Lancet Glob Health* 2019;7:e37–46.
2 Blencowe H, Lawn JE, Vazquez T, *et al*. Preterm-associated visual impairment and estimates of retinopathy of prematurity at regional and global levels for 2010. *Pediatr Res* 2013;74 Suppl 1:35–49.
3 Blencowe H, Cousens S, Jassir FB, *et al*. National, regional, and worldwide estimates of stillbirth rates in 2015, with trends from 2000: a systematic analysis. *Lancet Glob Health* 2016;4:e98–108.
4 Kong L, Fry M, Al-Samarraie M, *et al*. An update on progress and the changing epidemiology of causes of childhood blindness worldwide. *J AAPOS* 2012;16:501–7.
5 Fieß A, Nauen H, Mildenberger E, *et al*. Ocular geometry in adults born extremely, very and moderately preterm with and without retinopathy of prematurity: results from the Gutenberg Prematurity Eye Study. *Br J Ophthalmol* 2023;107:1125–31.
6 Holmström G, el Azazi M, Kugelberg U. Ophthalmological follow up of preterm infants: a population based, prospective study of visual acuity and strabismus. *Br J Ophthalmol* 1999;83:143–50.
7 Schalij-Delfos NE, de Graaf ME, Treffers WF, *et al*. Long term follow up of premature infants: detection of strabismus, amblyopia, and refractive errors. *Br J Ophthalmol* 2000;84:963–7.
8 Fieß A, Kölb-Keerl R, Knuf M, *et al*. Axial Length and Anterior Segment Alterations in Former Preterm Infants and Full-Term Neonates Analyzed With Scheimpflug Imaging. *Cornea* 2017;36:821–7.
9 Darlow BA, Clemett RS, Horwood LJ, *et al*. Prospective study of New Zealand infants with birth weight less than 1500 g and screened for retinopathy of prematurity: visual outcome at age 7-8 years. *Br J Ophthalmol* 1997;81:935–40.
10 O'Connor AR, Stephenson TJ, Johnson A, *et al*. Change of refractive state and eye size in children of birth weight less than 1701 g. *Br J Ophthalmol* 2006;90:456–60.
11 Fieß A, Elbaz H, Korb CA, *et al*. Low Birth Weight Is Linked to Age-Related Macular Degeneration: Results From the Population-Based Gutenberg Health Study (GHS). *Invest Ophthalmol Vis Sci* 2019;60:4943.
12 Pétursdóttir D, Holmström G, Larsson E. Strabismus, stereoacuity, accommodation and convergence in young adults born premature and screened for retinopathy of prematurity. *Acta Ophthalmol (Copenh)* 2022;100.
13 VanderVeen DK, Allred EN, Wallace DK, *et al*. Strabismus at Age 2 Years in Children Born Before 28 Weeks' Gestation: Antecedents and Correlates. *J Child Neurol* 2016;31:451–60.
14 Huang C-Y, Tou S-I, Lin H-J, *et al*. Risk of long-term ophthalmological complications in Taiwanese preterm infants: a nationwide cohort study. *BMJ Paediatr Open* 2024;8:e002279.
15 Hatt SR, Leske DA, Castañeda YS, *et al*. Association of Strabismus With Functional Vision and Eye-Related Quality of Life in Children. *JAMA Ophthalmol* 2020;138:528.
16 Howson CP, Kinney MV, Lawn JE. Born too soon: the global action report on preterm birth. March of dimes, pmnch, save the children, world health organization. 2012. Available: https://assets.publishing.service.gov.uk/media/57a08a76e5274a27b20005e3/201204_borntoosoon-report.pdf
17 Larsson E, Hellström A, Tornqvist K, *et al*. Ophthalmological outcome of 6.5 years children treated for retinopathy of prematurity: a Swedish register study. *Br J Ophthalmol* 2023;108:137–42.
18 VanderVeen DK, Bremer DL, Fellows RR, *et al*. Prevalence and course of strabismus through age 6 years in participants of the Early Treatment for Retinopathy of Prematurity randomized trial. *J AAPOS* 2011;15:536–40.
19 Hellgren KM, Tornqvist K, Jakobsson PG, *et al*. Ophthalmologic Outcome of Extremely Preterm Infants at 6.5 Years of Age: Extremely Preterm Infants in Sweden Study (EXPRESS). *JAMA Ophthalmol* 2016;134:555–62.
20 Kanukollu VM, Sood G. Secondary strabismus. In: *Strabismus*. 2025. Available: https://www.ncbi.nlm.nih.gov/books/NBK560782/
21 Mojon-Azzi SM, Kunz A, Mojon DS. Strabismus and discrimination in children: are children with strabismus invited to fewer birthday parties? *Br J Ophthalmol* 2011;95:473–6.
22 Fieß A, Wacker A, Gißler S, *et al*. Ophthalmic care of adults born preterm and full-term-results from the Gutenberg Prematurity Eye Study (GPES): Premature birth and ophthalmological care. *Ophthalmologie* 2023;120:608–19.
23 IQTIG. Institute for Quality Assurance and Transparency in Healthcare. Federal evaluation perinatal medicine: neonatology. data collection year 2022. 2023.
24 Voigt M, Fusch C, Olbertz D. Analyse des neugeborenenkollektivs der bundesrepublik deutschland 12Mitteilung Vorstellung engmaschiger Perzentilwerte (-kurven) für die Körpermaße Neugeborener. Geburtsh Frauenheilk; 2006.66. 956–70.
25 Bach M, Kommerell G. Determining visual acuity using European normal values: scientific principles and possibilities for automatic measurement. *Klin Monbl Augenheilkd* 1998;212:190–5.
26 Fieß A, Kölb-Keerl R, Schuster AK, *et al*. Prevalence and associated factors of strabismus in former preterm and full-term infants between 4 and 10 Years of age. *BMC Ophthalmol* 2017;17:228.
27 Elflein HM, Fresenius S, Lamparter J, *et al*. The prevalence of amblyopia in Germany: data from the prospective, population-based Gutenberg Health Study. *Dtsch Arztebl Int* 2015;112:338–44.
28 Fieß A, Gißler S, Hartmann A, *et al*. Visual acuity, amblyopia and refractive error in preterm children with and without retinopathy of prematurity – Results from the Gutenberg Prematurity Study Young (GPSY). *Acta Ophthalmol (Copenh)* 2025;Online First.
29 Greenland S, Senn SJ, Rothman KJ, *et al*. Statistical tests, P values, confidence intervals, and power: a guide to misinterpretations. *Eur J Epidemiol* 2016;31:337–50.
30 Yetkin AA, Turkman IH. Evaluation of clinical characteristics and risk factors of strabismus cases. *North Clin Istanb* 2023;10:157–62.
31 Chapron T, Pierrat V, Barjol A, *et al*. Gestational age, maternal smoking, neurological lesion and retinopathy predict strabismus at age 5.5 in preterm children. *Acta Paediatr* 2025;114:141–7.
32 Robaei D, Rose KA, Kifley A, *et al*. Factors associated with childhood strabismus: findings from a population-based study. *Ophthalmology* 2006;113:1146–53.
33 Khanna S, Sharma A, Ghasia F, *et al*. Prevalence of the Infantile Strabismus Complex in Premature Children With and Without Periventricular Leukomalacia. *Am J Ophthalmol* 2022;240:342–51.
34 Romero-Guzman GJ, Lopez-Munoz F. Prevalence and risk factors for periventricular leukomalacia in preterm infants. A systematic review. *Rev Neurol* 2017;65:57–62.
35 Jeon H, Jung J, Kim H, *et al*. Strabismus in children with white matter damage of immaturity: MRI correlation. *Br J Ophthalmol* 2017;101:467–71.
36 Ueda K, Tsuda K, Yamada T, *et al*. Incidence and Risk Factors of White Matter Lesions in Moderate and Late Preterm Infants. *Diagnostics (Basel)* 2025;15:881.
37 Muen WJ, Saeed MU, Kaleem M, *et al*. Unsuspected periventricular leukomalacia in children with strabismus: a case series. *Acta Ophthalmol Scand* 2007;85:677–80.
38 Chen Y-W, Lin S-A, Lin P-W, *et al*. The difference of surgical outcomes between manifest exotropia and esotropia. *Int Ophthalmol* 2019;39:1427–36.
39 Fieß A, Pfisterer A, Gißler S, *et al*. RETINAL THICKNESS AND FOVEAL HYPOPLASIA IN ADULTS BORN PRETERM WITH AND WITHOUT RETINOPATHY OF PREMATURITY: The Gutenberg Prematurity Eye Study. *Retina (Philadelphia, Pa)* 2022;42:1716–28.
40 Zhu H, You X, Jing Y, *et al*. Maternal Hypertensive Disorder in Pregnancy and Childhood Strabismus in Offspring. *JAMA Netw Open* 2024;7:e2423946.
41 Clarke WN. Common types of strabismus. *Paediatr Child Health* 1999;4:533–5.
42 Pierrat V, Marchand-Martin L, Arnaud C, *et al*. Neurodevelopmental outcome at 2 years for preterm children born at 22 to 34 weeks' gestation in France in 2011: EPIPAGE-2 cohort study. *BMJ* 2017;358:j3448.
43 AWMF. S2k-leitlinie augenaerztliche screening-untersuchung frühgeborene [s2k guideline on ophthalmologic screening examination of preterm infants]. 2020.
44 Mohan K, Sharma SK. Amblyopia in patients with intermittent exotropia. *J Clin Ophthalmol Res* 2023;11:36–9.
45 Hvid K, Nissen KR, Bayat A, *et al*. Prevalence and causes of infantile nystagmus in a large population-based Danish cohort. *Acta Ophthalmol* 2020;98:506–13.
46 Brodsky MC, Fray KJ, Glasier CM. Perinatal cortical and subcortical visual loss: mechanisms of injury and associated ophthalmologic signs. *Ophthalmology* 2002;109:85–94.
47 Jacobson L, Ygge J, Flodmark O. Nystagmus in periventricular leucomalacia. *Br J Ophthalmol* 1998;82:1026–32.
48 Allred EN, Capone A Jr, Fraioli A, *et al*. Retinopathy of prematurity and brain damage in the very preterm newborn. *J AAPOS* 2014;18:241–7.
49 Ricci D, Lucibello S, Orazi L, *et al*. Early visual and neuro-development in preterm infants with and without retinopathy. *Early Hum Dev* 2020;148:105134.
50 Pennefather PM, Clarke MP, Strong NP, *et al*. Risk factors for strabismus in children born before 32 weeks' gestation. *Br J Ophthalmol* 1999;83:514–8.

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