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ORIGINAL ARTICLE

Accommodative–vergence disorders in a paediatric ophthalmology clinical setting in Argentina

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Abstract

Purpose: To determine the frequency of potential non-strabismic accommodative–vergence anomalies (NSAVA) and investigate associations between NSAVA, refractive errors and age among children attending a paediatric ophthalmology clinic.

Methods: This study included children and adolescents aged 5–19 years attending an ophthalmology clinic with at least two follow-up visits. At their first visit, children had a comprehensive ophthalmic examination, including refractive error measurement by cycloplegic autorefraction and spectacles were prescribed if necessary. At the second visit, children had an examination of best-corrected visual acuity, convergence and accommodation to identify potential NSAVA. The relationship between age, sex, heterophoria and refractive error and potential NSAVA was assessed by a multivariable logistic regression model.

Results: A total of 384 children and adolescents were evaluated. Their mean age was 10.97 ± 3.07 years and 58.9% were females. Forty-two per cent of children failed the NSAVA tests and 34.1% had myopia (≤−0.50 D). Children who failed NSAVA tests self-reported a higher proportion of reading problems (73.7%) compared to those who passed the tests (26.3%; $p < 0.001$). Children with self-reported reading problems were more likely to have accommodative infacility (57.9%) compared with children without (42.1%; $p < 0.001$). Refractive error and age were not associated with failure in NSAVA tests ($p > 0.05$).

Conclusions: NSAVA was a frequent cause of vision problems found in a sample of children from an ophthalmology paediatric clinic. Thus, further research is necessary to understand the potential of public health policies to prevent, refer, diagnose and treat those conditions.

KEYWORDS
binocular vision, myopia, prevalence, reading

1 | INTRODUCTION

Non-strabismic accommodative and vergence anomalies (NSAVA) include accommodative insufficiency, accommodative excess and accommodative infacility as well as convergence insufficiency, convergence excess and fusional vergence dysfunction. These are vision anomalies which reduce binocular coordination and visual efficiency. The symptoms of NSAVA include headaches, eyestrain, loss of comprehension and avoidance of near work. The burden and consequences of NSAVA are numerous and include negative impact on the child's quality of life and academic performance. Baseline treatment of refractive errors improves binocularity. In a previous study, binocular vision dysfunction was reported to be associated with refractive error in Chinese young adults (Ma et al., 2019). However, there is mixed evidence with one study in African high school students reporting no association with binocular vision dysfunction and refractive error (Wajuihian, 2017).

There are no data on the frequency of NSAVA in children attending ophthalmic paediatric practices in Argentina. These dysfunctions may be missed if a thorough examination is not performed (Mandal & Kamath, 2020). In this study, we aimed to determine the frequency of aspects of NSAVA using simple tests that any ophthalmologist can perform in everyday practice to further refer

those patients to an orthoptic evaluation. The goal of this study was to highlight the need for eye care practitioners to routinely test for NSAVA as these dysfunctions may be missed out unless a complete orthoptic and binocular vision examination is performed. The intention of the study is also to increase the awareness among eye care professionals to assess symptomatology and perform simple diagnostic tests to identify NSAVA with subsequent referral to orthoptic evaluation. Findings are important for policy administration and planning of ophthalmological services. The specific objectives of the study are to: (1) determine the frequency of NSAVA and (2) investigate associations between NSAVA, refractive errors and age. The hypothesis tested was that there was no significant association between NSAVA and refractive error and age.

2 | MATERIALS AND METHODS

This was an observational study which examined children and adolescents aged 5–19 years with at least two follow-up visits in an ophthalmology paediatric clinic located in Quilmes, Greater Buenos Aires, Argentina. Data were collected between October and November 2021. All children attending the clinic have annual or semi-annual visits for routine ocular examinations. Children with acute conjunctivitis, chalazion, blepharitis, trauma or other acute pathologies were excluded from the study. Patients with ocular pathologies, such as coloboma, congenital glaucoma, Duane syndrome, history of strabismus surgery, anterior polar cataract, retinopathy of prematurity or amblyopia were also excluded. The study was conducted in accordance with the tenets of the Declaration of Helsinki. Verbal assent from the children and verbal consent from the parents was obtained from all subjects after the nature of the study was explained. As there was no therapeutic intervention within the protocol, the current legislation in Argentina does not consider authorization by an accredited ethics committee to be necessary. Nevertheless, The Argentinian Council Ethics Committee was consulted and as no intervention or new test was administered, the Committee suggested that approval was not necessary. Data were completely anonymized and in full compliance with data protection laws.

2.1 | Refractive error assessment (first visit)

At their first visit, children and adolescents attending the clinic were submitted to a comprehensive ophthalmic examination, including visual acuity and routine refractive error measurement by cycloplegic autorefraction. Cycloplegia was induced with two drops of cyclopentolate 1% instilled in each eye 5 min apart. Subsequently, cycloplegic autorefraction was performed with a handheld auto-refractor (2WIN, Adaptica, Italy) at least 40 min after the last eye drop. When necessary, spectacles were prescribed according to the American Academy of Ophthalmology Clinical Practice Patterns. Spherical equivalent (SE) was calculated using the standard formula (SE = sphere + ½*cylinder). Myopia was defined by an SE of less than or equal to −0.50 dioptres (D) and high myopia by an SE of less than or equal to −5.00 D. Emmetropia was defined by an SE ranging between >−0.50 D and +0.50 D. Hyperopia was defined by an SE ranging between >+0.50 D and +2.00 D and high hyperopia by an SE greater than +2.00 D. Anisometropia was defined by a difference of 1.00 D or more between the SE of both eyes and anisoastigmatism was defined by a difference of 1.00 D or more in the astigmatism of both eyes.

2.2 | Visual acuity and accommodative and vergence assessment (second visit)

At the second visit, consecutive unselected children and adolescents who came to the clinic for routine ocular annual examination had a comprehensive examination of best-corrected visual acuity, convergence and accommodation. All included children had measures of refractive error with cycloplegia from their first visit. The follow-up time between the first and second visit was 6 to 12 months. Best-corrected visual acuity at the second visit was compared with the first visit to ensure that refraction had not changed. Figure 1 shows the flow chart of the study design. In Argentina, it is common to maintain regular ophthalmological annual follow-ups until the age of 20 years, even if previous examinations are normal. All visual functions were assessed with previously prescribed spectacles, if applicable. Best-corrected visual acuity was measured with a retro-illuminated Snellen Optotype Projector (Tumbling E, Rusner, Argentina). Accommodative–vergence assessment included the near point of convergence (NPC), heterophoria measurement at near and accommodative facility testing. NPC was measured using the push up technique with an accommodative target and a ruler. NPC was measured three times and registered as insufficient when it was greater than 5 cm. Previous studies suggested that children below 8 years have lower NPC and the use of NPC >5 cm may be important to differentiate symptomatic elementary school children and adults (Chen et al., 2000; Maples & Hoenes, 2007; Scheiman et al., 2003).

The heterophoria was measured with Thorington phoria test with an accuracy of 1 prismatic diopter (PD) and a millimetric chart held at 33 cm (provided by Lab. Pfortner, Argentina). Normal heterophorias were considered in the range from 2 PD esophoria to 8 PD exophoria (Dwyer, 1991). Negative values indicate exophoria and positive values indicate esophoria. The presence of a vertical heterophoria of 1 PD or more was considered an abnormal result. Monocular accommodative facility (MAF) test for each eye was measured with ±2.00 D flippers using a 0.6 M letter at 0.4 m for a period of 1 min (expressed in accommodative facility cycles per minute). Insufficient values were considered when MAF was below six cycles per minute. A child was considered to have potential NSAVA when NPC >5 cm or MAF <6 cycles per minute. The examination also included a detailed general medical and ophthalmic history allowing the patient to self-report visual symptoms such as headaches and reading problems in a non-structured pattern.

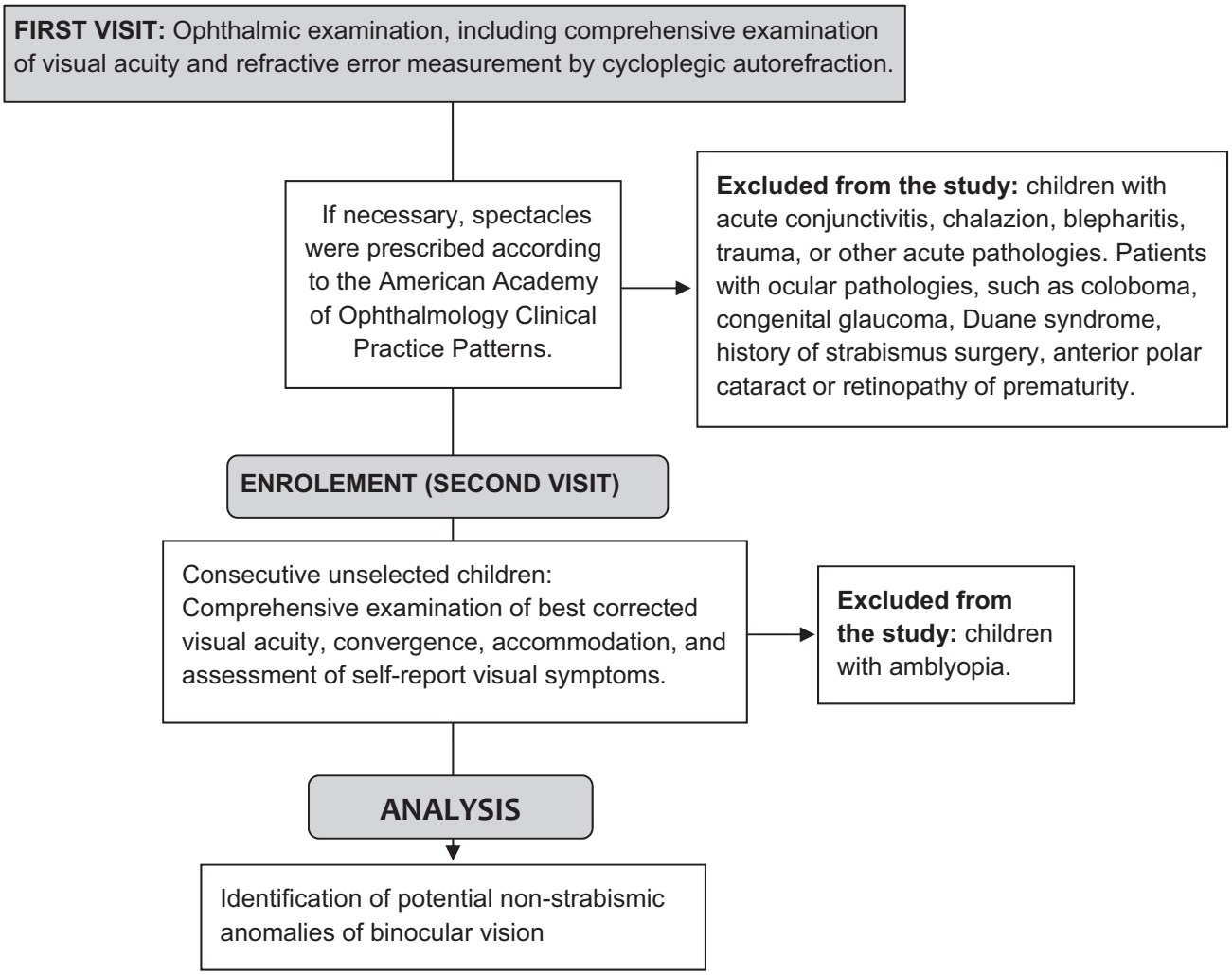

FIGURE 1 Flow chart of the study design.

2.3 | Statistical analysis

The sample size calculation for an expected proportion of 20% frequency of binocular disorders with a $p = 0.05$ and a precision of 4% rendered a sample of 384 subjects. Means and standard deviations were calculated for linear variables and percentages for discrete variables. To determine which risks factors were associated with the failure in accommodative–vergence tests, we compared age, gender, heterophoria and SE in children who failed the tests ($n = 162$) and children who did not fail the tests ($n = 186$) after excluding children with strabismus from the analysis. The outcome potential NSAVA was analysed as a categorical variable (with anomalies/without anomalies). Analyses of associations were performed using a multivariable logistic regression model. Risk factors such as age, heterophoria and SE were analysed as continuous variables (per unit change). SE of right and left eyes was highly correlated ($r = 0.89$, $p < 0.001$) so the analysis was performed with the SE of right eyes only. Odds ratios (OR) were estimated using backward stepwise multivariable logistic regression model. A value of $p < 0.05$ was chosen for statistical significance. All statistical analyses were carried out with SPSS (IBM, United States, version 26).

3 | RESULTS

A total of 384 children and adolescents were included in the analysis. The mean (± standard deviation) age was 10.97 ± 3.07 years, and 226 (58.9%) were females (Table 1). Their mean cycloplegic SE was −0.18 ± 1.92 D. The mean near phoria was −1.22 ± 4.70 PD. In total, 47.4% of the children had orthophoria, 33.9% had esophoria and 17.7% had exophoria.

The frequency of refractive errors, strabismus and potential NSAVA is provided in Table 2. Myopia was diagnosed in 34.1% of the children and high myopia in 1.8% (total of 35.9%). In children aged 5–11 years, the most predisposed to develop high myopia in adulthood, there were 61 children with myopia. Older children (12–19 years) had significantly higher myopic SE (−0.88 D vs. −0.04 D; $p < 0.001$) compared with younger children (5–11 years). Thirty-five (9.1%) children had anisometropia and 39 children (10.2%) had an anisoastigmatism of more than 1.00 D. There were 10 children (2.6%) with an anisoastigmatism of 2.00 D or more. Self-reported reading problems were referred by 9.9% ($n = 38$) of children and headaches by 4.2% ($n = 16$) children.

Forty-two per cent of children and adolescents failed the accommodative–vergence tests, including children with an NPC >5 cm (12.3%) or MAF <6 cycles per minute

TABLE 1 Demographic and eye characteristics of included children in the study ($n=384$).

Demographic and eye characteristics	Number of children	Mean±SD or %
Age (years)	383	10.97±3.07
Age groups (%)		
5–11 years	241	62.9%
12–19 years	142	37.1%
Gender (%)		
Boys	158	41.1%
Girls	226	58.9%
Spherical equivalent (D)	384	−0.18±1.92
Heterophoria (PD)	380	−1.22±4.70
Orthophoria	182	47.9%
Exophoria	68	17.9%
Esophoria	130	34.2%

Abbreviations: D, diopter; SD, standard deviation.

TABLE 2 Frequency and number of children and adolescents with refractive errors, strabismus and potential accommodative–vergence disorders ($n=384$).

Diagnosis	Number of children	%
Refractive errors		
Myopia (SE −0.50 D to −4.99 D)	131	34.1%
High myopia (SE ≤−5.00 D)	7	1.8%
Emmetropia (SE >−0.50 D to 0.50 D)	142	37.0%
Hyperopia (SE >0.50 D to 2.00 D)	69	18.0%
High hyperopia (SE >2.00 D)	35	9.1%
Total	384	100%
Strabismus		
Accommodative strabismus	18	4.7%
Intermittent exotropia	18	4.7%
Potential non-strabismic anomalies of binocular vision		
Normal binocular vision	186	48.4%
NPC >5 cm	47	12.2%
MAF <6 cycles per minute	76	19.8%
NPC >5 cm & MAF <6 cycles per minute	39	10.2%
Total	384	100%

Abbreviations: NPC, near point of convergence; MAF, monocular accommodative facility.

(19.8%) or both (10.2%; Table 2). Among non-strabismic children, the mean MAF was 9.80±4.76 cycles per minute.

Potential accommodative–vergence disorders were evaluated in 348 children. Children with strabismus were excluded from the analysis (Table 3). Among non-strabismic children, those who failed the accommodative–vergence tests were more likely to be girls ($p=0.020$) and to have exophoria ($p=0.028$; Table 3). SE was not significantly different between the groups who failed or not the accommodative and vergence tests ($p=0.87$). Age by year or age groups were also not significantly different between the two groups of NSAVA and without NSAVA ($p>0.05$). Children who failed the accommodative–vergence tests reported higher proportion of self-reported reading problems (73.7%) compared with children who did not fail the tests (26.3%; $p<0.001$). Children with reading problems were more likely to have accommodative infacility (57.9%) compared with children without accommodative infacility (42.1%; $p<0.001$). There were no significant differences between the proportion of self-reported reading problems and refractive error ($p=0.28$) or the proportion of accommodative infacility and refractive error ($p=0.84$).

There were no significant differences in SE by NPC groups (NPC ≤5 cm = −0.10±1.88 D; NPC >5 cm = −0.17±2.14 D; $p=0.74$). SE was significantly more hyperopic in children with esophoria (0.55±2.14 D) compared to children with orthophoria (−0.10±1.65 D; $p=0.004$).

Heterophoria values were significantly different for hyperopic children compared with emmetropic (0.41±4.42 PD vs. −1.48±4.54 PD; $p=0.036$) and high hyperopic children (1.08±4.62 PD; $p=0.021$). Heterophoria values in hyperopic ($p=0.001$) and high hyperopic ($p=0.001$) children also differed significantly compared with myopic children (−2.21±4.60 PD). Although, there was a tendency for older children (12–19 years) to have higher exophoric values compared with younger children (5–11 years), this tendency was not significant (−1.85 vs. −1.03; $p=0.09$). The correlation between heterophoria values and age was not significant ($r=-0.07$; $p=0.20$). Similarly, the correlation between heterophoria values and SE was not significant ($r=0.09$; $p=0.10$). Age by year (β=−0.05; 95% CI: −0.13–0.03; $p=0.20$) and SE (β=0.02; 95% CI: −0.02–0.07; $p=0.26$) were not significantly associated with heterophoria values. There were no significant differences in the heterophoria values for NPC groups ($p=0.14$). MAF was significantly lower in children with NPC >5 cm ($p=0.08$). Although, children with myopia had lower MAF (9.11 cycles per minute) compared with children without myopia (9.49 cycles per minute), the difference was not statistically significant ($p=0.42$).

Potential NSAVA were associated with female sex (Odds ratio [OR]=1.62; 95% CI: 1.04–2.52) and heterophoria (OR=1.07; 95% CI: 1.02–1.13; Table 4) in the multivariable model including age by year. Similar results were found when age by groups as tested, with only gender ($p=0.029$) and heterophoria ($p=0.014$) being significantly associated with NSAVA. In a subgroup analysis by age groups of 12–19 years ($n=142$) and 5–11 years ($n=241$), only female gender remained as significantly associated with NSAVA in the 5–11 years group (OR=2.35; 95% CI: 1.32–4.21).

4 | DISCUSSION

This study describes the frequency of potential NSAVA using simple tests among children and adolescents attending a paediatric ophthalmology clinic. Approximately 40% of children and adolescents failed those tests. The results of this study show that mild disturbances of accommodation and vergence in non-strabismic children are frequent in clinical practice in this setting. Therefore, if this simple study is replicated and confirmed, it may be necessary to educate paediatric ophthalmologists so that they can identify, treat and refer those children to orthoptics when necessary if a potential NSAVA is suspected to further confirm the diagnosis.

Up to 9.9% of children and adolescents included in this study spontaneously reported reading difficulties and

TABLE 3 Comparison of demographic characteristics, spherical equivalent, refractive error and heterophoria in children and adolescents with and without potential accommodative–vergence disorders ($n=348$).

	Potential accommodative–vergence disorders[a]				
	Without anomalies		With anomalies		
Demographic characteristics	*n*	Mean±SD or %	*n*	Mean±SD or %	*p*
Age (years)	185	10.8±3.0	162	11.3±3.2	0.18
Age groups					
5–11 years	122	56.2%	95	43.8%	0.16
12–19 years	63	48.5%	67	51.5%	
Gender					
Boys	86	61.0%	55	39.0%	0.020
Girls	100	48.3%	107	51.7%	
Spherical equivalent (D)	186	−0.32±1.75	162	−0.29±1.85	0.87
Myopia and high myopia	64	49.2%	66	50.8%	0.43
Emmetropia	74	54.8%	61	45.2%	
Hyperopia and high hyperopia	48	57.8%	35	42.2%	
Heterophoria (PD)	183	−0.68±3.55	162	−2.02±5.02	0.004
Orthophoria	94	53.1%	83	46.9%	0.028
Exophoria	22	38.6%	35	61.4%	
Esophoria	67	60.4%	44	39.6%	

Note: Mean±standard deviation for continuous variables and percentages for categorical variables. *p* indicates difference in participant characteristics by outcome status.
Abbreviations: D, dioptre; n, number.
[a]Potential accommodative–vergence disorders were evaluated in 348 children. Children with strabismus were excluded from the analysis.

TABLE 4 Association of key risk factors with potential accommodative–vergence disorders ($n=348$).

Demographic and eye characteristics	Potential accommodative–vergence disorders			
	Unadjusted OR (95% CI)	*p*	Multivariable OR (95% CI)[a]	*p*
Age (years)	1.05 (0.98, 1.12)	0.18	1.04 (0.97, 1.11)	0.23
Gender (%)				
Boys	Reference		Reference	
Girls	1.67 (1.08, 2.58)	0.020	1.62 (1.04, 2.52)	0.033
Heterophoria (−1 PD increase)	1.08 (1.02, 1.13)	0.005	1.07 (1.02, 1.13)	0.013
SE (+1 D increase)	1.02 (0.90, 1.16)	0.72	1.07 (0.93, 1.22)	0.34

Abbreviations: CI, Confidence intervals; OR, Odds ratio.
[a]Multivariate model includes age, gender, heterophoria and SE ($n=344$).

among them 57.9% had accommodative infacility. There were no significant differences between the proportion of children with reading problems and refractive error, or the proportion of children with accommodative infacility and refractive error. The results of the association between refractive error and reading problems in children have been mixed, with some studies reporting no association (Dusek et al., 2010; Latvala et al., 1994). A recent meta-analysis of five studies found that children with uncorrected hyperopia had worse educational performance and reading skills when compared with emmetropic and myopic children (Mavi et al., 2022). In another study, children with uncorrected hyperopia had more reading errors, lower accuracy and lower reading speed when compared with children without hyperopia or with corrected refractive error (Lanca, 2017). Correction of low-moderate hyperopia may increase speed of reading as there is an improvement in accommodative performance during sustained near activity in some school children (Ntodie et al., 2021; van Rijn et al., 2014). Thus, prescribing hyperopic correction in those children may benefit performance in near vision tasks. Additionally, orthoptic treatment may be necessary (Shukla, 2020). Studies have shown that orthoptic treatment including vergence and accommodative training is an effective method to treat and improve the symptoms (Chen et al., 2021; CITT-ART Investigator Group, 2019; Cooper et al., 1987; Weisz, 1979).

This study has several limitations. This was not a multicentric study; thus, the results may not represent the entire population. The participants were from Quilmes, Greater Buenos Aires, which may induce cluster effects. Patients who visit paediatric ophthalmology clinics are more likely to have complaints of a visual anomaly than if they would have been selected at random from the general population. We found that a higher proportion of children with anomalies of NPC and MAF reported reading problems compared with children who had no anomalies of NPC and MAF. However, reading problems were self-reported and the study had a cross-sectional design. Thus, there may be a bias as reading anomalies

were not objectively measured, and we cannot infer causality because a temporal sequence cannot be established. In our study, we did not measure fusion amplitudes and stereoacuity, important measures of binocular vision. Reduced stereoacuity has been reported to affect complex visuomotor tasks, including reading ability and academic performance in children (Kulp & Schmidt, 1996, 2002). Potential NSAVA was defined by the use of NPC and accommodative facility results. Further research is necessary to determine the best simple tests for screening NSAVA in an ophthalmology clinical setting.

The strengths of this study include the use of cycloplegia to determine the refractive error. In a previous study, the 2WIN has shown measures of refractive error (sphere and spherical equivalence) consistent and comparable with retinoscopy and an autorefractor when children where under the effect of cycloplegic drops (Yalcın et al., 2017).

5 | CONCLUSIONS

Failure in simple tests for accommodative–vergence disorders was frequent in clinical practice. Children who failed the accommodative–vergence disorders tests were more likely to report reading problems. Those children and adolescents with reading problems were also more likely to have accommodative infacility. More research is needed, including well-designed epidemiological studies, to ascertain the prevalence of binocular vision anomalies and develop health policies with the aim of improving visual health of children. Simple clinical studies like the present one could also help in providing data of the workload of paediatric ophthalmologists.

CONFLICT OF INTEREST STATEMENT

None of the authors have any conflicts of interest to disclose.

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