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Analysis and applicability of protocols to diagnosis of refractive errors in children

Análisis y aplicabilidad de los protocolos para el diagnóstico de errores refractivos en niños

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ABSTRACT
Currently, a large part of the world population does not have access to quality visual health services. Most of this population lives in developing countries, thus it is necessary to screen the general population to identify ocular abnormalities such as refractive errors and amblyopia in schoolchildren. The protocols for complete visual screening or examination vary widely regarding the type of tests and procedures, although most of them use visual acuity (VA) and refraction as the main diagnostic criteria. These clinical tests should have good quality and precision, that is, a high sensitivity and specificity. Unfortunately, in most clinical and epidemiological studies, the quality and accuracy of the tests used are unknown, which makes it difficult to compare results and to estimate the real conditions of visual problems in the population. Therefore, the objective of this literature review was to describe the main tests and protocols used in epidemiological and clinical studies for the detection of refractive errors in children.

Keywords: vision screening, refractive errors, diagnostic tests, children.

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RESUMEN

Actualmente, una gran parte de la población, especialmente de los países en desarrollo, no tiene acceso a servicios de salud visual de calidad. La población infantil es la mas afectada, dado que la maduración del sistema visual ocurre en los primeros años de vida, por lo cual es necesario realizar tamizaje o examen visual completo en esta población para identificar anomalías oculares como errores de refracción y ambliopía en escolares. Los protocolos para el tamizaje visual o examen completo varían ampliamente en el tipo de pruebas y procedimientos, aunque la mayoría utiliza la agudeza visual (AV) y la refracción como principales criterios diagnósticos. Estas pruebas clínicas deben tener buena calidad y precisión, es decir, una alta sensibilidad y especificidad. Desafortunadamente, en la mayoría de los estudios clínicos y epidemiológicos se desconoce la calidad y la precisión de las pruebas utilizadas, lo cual dificulta la comparación de los resultados y la estimación de las condiciones reales de los problemas visuales detectados en los países y en el mundo. Por lo tanto, el objetivo de la presente revisión de la literatura fue describir las principales pruebas y protocolos utilizados en estudios epidemiológicos y clínicos para la detección de errores refractivos en niños.

Palabras clave: tamizaje visual, errores refractivos, agudeza visual, refracción, test diagnósticos, niños.

INTRODUCTION

The maturation of the human visual system occurs during the first six years of life, in which the visual stimuli that reach the retina of both eyes need to be properly focused and aligned with each other, otherwise it can lead to the development of amblyopia, with permanent and irreversible consequences (1). According to the World Health Organization (WHO) (2), there are approximately 19 million 15-year-old children and younger without access to eye care and ocular health, 12 million of whom suffer from uncorrected refractive errors. Approximately 5.5 % of these children are students, whose education is seriously affected by these refractive errors, although they can easily be corrected by up to 80 % with lenses as long as there are no other associated neurological defects and the adequate services of health are available for the entire population.

Blindness and low vision are a public health problem worldwide, with high socio-economic costs, which are borne by the family nucleus and society. This is due to the lack of access to health services, which is reflected in the high prevalence of curable blindness (4,5). The estimated annual cost of loss of productivity due to refractive impairment in the world is 269 billion international dollars (6,7). In Colombia, the negative impact on the country's gross domestic product (GDP) caused by blindness and decreased visual acuity could be between 2 billion and 3209 billion dollars. Therefore, visual impairment implies a high economic and social cost for the region (4). Moreover, visual defects in children lead to school failure and prevent the increase in number of higher education students, which barely reach 20 % of the population (7).

Refractive errors are detected through visual screening in promotional campaigns for eye care or complete clinical examination, which are generally applied in primary care services. Given that a large part of the population has no access to quality visual health and that they are mostly part of developing countries, it is necessary to conduct a screening of the general population to identify ocular abnormalities such as errors refraction and amblyopia in schoolchildren (7). This type of screening should include at least the assessment of monocular visual acuity and a pinhole to detect a greater visual impairment (8), which can be done by teachers or health professionals (i.e., nurses, doctors, optometrists and ophthalmologists) trained to perform an early detection of refractive error in pre-school children, followed by refraction, prescription of glasses, and referral to a specialized health center if they require any surgical or medical treatment.

In children under 3 years of age, vision is evaluated based on the child's ability to set and follow monocular and binocular objects (9). A standard strategy of evaluation is to define if each eye can focus on an object, maintain fixation and then follow the object from various positions. The failure of these maneuvers indicates a significant visual impairment, and therefore, if poor binocular fixation and follow-up is observed after 3 months of age, the child is suspected to have significant bilateral abnormalities of the eye or brain, and referral for further vision assessment is recommended (1).

The American Academy of Ophthalmology, Pediatrics, Optometric, Family Medicine and Pediatric Ophthalmology and Strabismus confirms the need for early vision assessment and recommend visual examination in preschool at least once a year in order to detect the presence of amblyopia or risk factors, in addition to the previously mentioned assessment by physical examination and with specialized instruments (autorefractors), when available (10-14). All these associations suggest measuring monocular visual acuity and detection of ocular misalignment, although the age at which the specific tests recommended begins vary between groups; generally, though, it should be performed after the child is 3 years old (15). However, only the American Academy of Family Physicians reports that current evidence is insufficient to assess the balance of benefits and harms of exploration vision in children under 3 years (14).

After 3 years of age, visual examination should include testing visual acuity (Snellen, Lea symbols, and HOTV), Bruckner, Refraction (static retinoscopy, dynamic, cycloplegic, and autorefractometer), Ocular Motility (fixing stability, saccadic function, next convergence point), binocular vision (cover unilateral and alternating test, Hirschberg, Krimsky, stereopsis, positive and negative fusional vergence), and color vision (10-14,16).

Following a similar protocol with children between the ages of 6 and 14, the Clinical Refraction Guide recommends that pediatric vision screening should include measurement of visual acuity, cover test, Hirschberg, stereopsis, convergence and pupillary red, by using basic elements such as optotypes, occluder, attachment figures, flat mirror, and stereopsis test, while a full exam has all these tests as well as assessment of refraction and examination of the anterior pole and retina by direct ophthalmoscopy (8).

Protocols for visual screening or complete examination vary widely in the type of tests and procedures, although most of them use visual acuity (VA) and refraction as the main criteria, respectively (17,18). These clinical trials must have good quality and accuracy, which means high sensitivity and specificity. Unfortunately, in most clinical and epidemiological studies, the quality and accuracy of the tests used is unknown, making it difficult to compare the results and the estimation of the actual conditions of visual problems in the population. Therefore, the purpose of this literature review was to describe the main tests and protocols used in epidemiological and clinical studies for detection of refractive errors in children.

VISUAL ACUITY

Assessment of visual acuity in children with different tests is performed according to age and schooling and should use a chart that the child is able to understand. Ian Bailey and Jan Lovie created the LogMAR chart in order to establish a standard visual acuity test in which the only significant variable between one line and another was size (19). Table 1 describes different charts frequently used in the practice of pediatric optometry, recommended age to perform the tests, and their corresponding description.

After developing the Snellen charts, many variations were made in the sequence size, diagram and optotypes design, in order to create a widely accepted standard chart that has different sequences of letters and the same amount of letters in each row. The LogMAR chart's design (logarithm of

TABLE 1. **Visual acuity assessment test in children from 2 years of age**

Test	Description	Age
New York Lighthouse	Cards with three easily distinguishable figures (apple, home, and umbrella) are shown from the largest to the smallest at a distance of 3 m.	2-3 years
Landolt C test	Directional type test comprising a series of circles having a space on the figure that must be placed right, left, up or down. The test it must be done at a distance of 3 meters.	
Allen cards	Four cards with seven schematic figures (horse, phone, cake). The figures are identified from various distances, starting at 3 meters.	2-4 years
LEA symbols	Cards with symbols (circle, square, apple, and house) that have been carefully studied after a rigorous scientific process to facilitate the matching of the symbols with the ones on the card located 3 m away. The symbols decrease in size and distance from top to the bottom of the booklet to create the knockout effect in LogMAR form.	
HOTV	Mating test to identify the letters *H*, *O*, *T*, and *V*. The letters decrease in size from top to bottom of the chart, and it is done at a distance of 3 m in LogMAR form.	Over 4 years
Directional E	Chart with the letter *E* facing different directions (up, down, left, and right), from largest to smallest at 3 meters.	
Snellen	Chart with 11 lines of letters at 4 meters. The first line consists of a very large letter and each bottom row has an increasing number of letters that are progressively smaller, without diminishing the distance between the letters.	
ETDRS	Chart that maintains 5 letters in each row, the spacing between each letter being proportional and giving the characteristic of a triangular configuration; it is typically evaluated from a distance of 2 or 4 meters.	6 years
Unicef	*E* directional chart that only considers three lines of evaluation from 20/40 to 20/20. It is usually evaluated from a distance of 2 or 4 meters.	Over 6 years

Source: Taken from the American Academy of Pediatrics (20) and Prevent Blindness America (21).

the minimum angle of resolution) arose from the need for research in order to determine variability retest in measurement of visual acuity for people with low vision, which improved the accuracy of measurement, and it was adopted in several studies as the gold standard for measuring visual acuity in different populations (19,22).

Although the measurement of visual acuity with a single test does not detect the refractive error reliably, this feature is the first measure of visual function in both clinical practice and research. Depending on the procedure, as well as on the chart and the age of the patient, visual acuity shows variability in repeatability and reproducibility and also in sensitivity and specificity (Table 2) (23,24).

The ETDRS chart can be used to predict most refractive errors in children in a sensitive and specific manner by using as a cutoff equal to 0.28 logMAR or worse; the test time is also shorter and has good accuracy compared to the standard test procedure (28). Studies such as those performed by Tong et al. in 2002 concluded that the measure of the logMAR visual acuity with the ETDRS chart is a screening tool accurate for refractive errors such as myopia and astigmatism, because the visual acuity threshold detected 87.6% of children with myopia; however, in this study the number of children defined as "farsighted" was very small, and it is therefore impossible to assess the true effectiveness of the test to detect hyperopia. Considering the cutoff visual acuity of 0.28 LogMAR, levels of sensitivity and

TABLE 2. **Percentage of sensitivity and specificity of visual acuity charts for the detection of refractive errors**

Year of study	Analyzed test (gold standard)	Age (years)	Sensitivity (% [IC 95%])	Specificity (% [IC 95%])
Moganeswari et al., 2015 (25)	ETDRS LogMAR AV 0.28 (cycloplegic autorefraction)	7-9	72 (68-76)	97 (95-98)
The Vision in Preschoolers (VIP) study group, 2004 (26)	LEA symbols (full review)	3-5	61 (41-77)	94 (90-94)
	HOTV (full review)		54 (41-72)	93 (90-94)
Ying, 2005 (27)	E-CHART (full review)	3-6	99 (91-99)	15 (9-23)

specificity were satisfactory; however, if a cutoff point higher is selected, specificity increases but, as a result, sensitivity is reduced. It is for this reason that, in investigations where decreased visual acuity is prevalent, it is not recommended to use tests to detect refractive errors with a specificity of less than 95 % (24).

The Vision in Preschoolers (VIP) study group created the first multicenter study to determine the validity of a protocol and their 11 visual tests for detecting the four main vision disorders: amblyopia, strabismus, uncorrected refractive error, and reduced visual acuity in children under 6 years of age (26). This study concluded that the most accurate test for detecting significant refractive error were refraction without cycloplegic (74 %), autorefractor Retinomax (66 %), SureSight Vision Screener (63 %), and Lea Symbols (58 %), which shows the importance of evaluating other visual functions different to visual acuity for determining refractive errors in children through visual screening, considering that, in this same research, all tests for detecting reduced visual acuity had sensitivities of less than 50 %.

Overall, the most important aspects when making a visual screening in preschool children is the selection of tests that require age-appropriate child cognitive skills (testability), reliability testing, and the ability of the test to accurately differentiate children with an eye disorder from children without one (sensitivity and specificity). In the latter respect, the above studies have shown that, for assessing preschoolers (from 3 to 6 years of age), it is advisable to use charts in LogMAR scale, such as the Lea symbols or the HOTV test, since both provide similar results and are easy to understand for this population with good sensitivity and specificity levels. Moreover, in children older than 6, it is recommended to use the ETDRS chart, which, although initially designed for adults, provides a measure of repeatable visual acuity in children and is considered the gold standard for measuring visual acuity in clinical practice (29).

REFRACTION

Retinoscopy is the objective test that provides greater information on the refractive state of the patient by neutralizing retinal reflection, assessing their characteristics (brightness, shading, movement speed and width of reflection), through different techniques (30):

1. *Static Retinoscopy* objectively measures the refractive state of the eye while the patient fixates an object located in far vision in order to keep the accommodation relaxed, is offset according to the working distance of the examiner (31).

2. *Dynamic retinoscopy* is a monocular technique described by Merchán in 1993, in which the patient should set an object at a distance of 40 cm in order to control accommodation. The compensation is performed according to the patient's age, considering that before the age of 40, the offset value is 1.25 D (32).

3. *Cycloplegic retinoscopy* is based on the same technique as static retinoscopy but with prior application of a pharmacological agent that inhibits the accommodative power of the eye, blocking the function of the ciliary muscle (33); the working distance and the ciliary muscle tone is compensated, varying between 0.50 and 0.75 D, depending on the drug used (34).

Use of static retinoscopy is not recommended in children, since variations may occur in the working distance by the examiner or failures in the fixation distance of the patient, generating a loss of control of the fixation and thus a failure in relaxation of accommodation, leading to obtaining differences of more than 1.0 D between values (35). Conversely, cycloplegic retinoscopy is more accurate and useful in uncooperative patients who have accommodative problems; however, several disadvantages are apparent in their application, such as adverse effects by the use of cycloplegic drops and need for highly qualified human resources to carry out the test. Similarly, in some Latin American countries, the law prohibits optometrists to use drugs as diagnostic means; for this reason, and as an alternative to cycloplegic refraction, monocular dynamic retinoscopy can be used in schoolchildren when the examiner requires to monitor the refractive status of the child, controlling their accommodation without instillation of the drug (36,37).

Studies conducted by the VIP showed that dynamic retinoscopy and auto refractometer (Retinomax and SureSight) are highly reliable and accurate in identifying amblyopia, strabismus and refractive errors in preschool children (38,39). The three tests have shown a high performance in detection myopia and astigmatism; similarly, the test was also good for detecting higher hyperopia to 3.25 D, which justifies the fact that, despite the difference between the test and the types of refractive errors, implementing retinoscopy in visual screening provides greater reliability in detecting specific ametropic levels. Thus, it has been shown that dynamic retinoscopy and the auto refractometer have performed better than visual acuity tests for detection of refractive errors in children (40). Therefore, it is necessary to compare sensitivity by combining specific objective tests that include the best test of each, considering that, when using retinoscopic testing and visual acuity testing simultaneously improves the detection of significant visual impairment.

Thus, although refraction and visual acuity are more valid techniques for detecting refractive errors, in both clinical examination and visual screening they are used with other tests that improve the efficiency and accuracy of diagnosis. Table 3 shows the tests suggested by the American Academy of Pediatrics for visual screening according to age, during childhood and indications of referral to ophthalmologist or optometrist (20).

TABLE 3. **Evaluation techniques for visual screening by age group**

Recommended age	Method	Indications for referral
Newborn to 3 months	Red retinal	Abnormal or asymmetric
	Inspection	Structural abnormality
3 to 6 months	Fixing and follow up	Fixing failure and follow up
	Red retinal	Abnormal or asymmetric
	Inspection	Structural abnormality
6 to 12 months until it is possible to measure visual acuity	Fixing and follow up with each eye	Fixing failure and follow up
	Alternating occlusion	Refusal to occlusion of either eye
	Corneal reflex	Asymmetric
	Red retinal	Abnormal or asymmetric
	Inspection	Structural abnormality
3 years	Monocular visual acuity	Follow specific directions on making visual acuity
	Corneal reflex cover-uncover	Asymmetric corneal reflex or reattachment movements to cover-uncover
	Red retinal	Abnormal or asymmetric
	Stereo acuity	Titmus test
	Inspection	Structural abnormality
5 years	Monocular visual acuity	Less than 20/40 or two lines of difference between the two eyes
	Corneal reflex cover-uncover	Asymmetric corneal reflex or reattachment movements to cover-uncover
	Red retinal	Abnormal or asymmetric
	Stereo acuity	Titmus test
	Inspection	Structural abnormality
Every 1 to 2 years after 5 years	Monocular visual acuity	Less than 20/30 or two lines of difference between the two eyes
	Corneal reflex cover-uncover	Asymmetric corneal reflex or reattachment movements to cover-uncover
	Red retinal	Abnormal or asymmetric
	Stereo acuity	Titmus test
	Inspection	Structural abnormality

Source: American Academy of Ophthalmology, Refractive Errors, Preferred Practice Pattern (11).

The protocols used in epidemiological studies with larger national and global coverage, including the full visual examination or screening for detection of refractive errors in children are described:

VISION IN PRESCHOOLERS STUDY GROUP (FULL EXAMINATION)

This protocol is the gold standard used in optometric examinations of children by the American Academy of Optometry (41). The VIP conducted a multicenter and multidisciplinary study in two phases to evaluate the performance of visual tests to identify preschool children with amblyopia, strabismus, and significant refractive errors or reduced visual acuity. A total of 2588 children were examined during Phase I, and the following methods for screening eye disorders were used: retinoscopy, autorefractometer (Retinomax), Lea symbols, and the HOTV visual acuity, stereo acuity with Dot E (Table 4) (39).

TABLE 4. **Characteristics of the VIP protocol for visual assessment in children**

Test	Instrument	Technique
Color vision	F2	It contains 4 cards (purple square, black square, blue square, and green square). Ask the child to point to the card with the black square in order to know if the child is able to identify the figure, then present the 4 cards up to 5 times, switching the cards from left to right. Indicate whether the child is able to identify the location of the black square on at least 4 of the 5 presentations. Do the same with the other colors.
Diopter lens power	Frontofocometer	Focus the lensometer to 0 D, place the patient's glasses on it, measuring the right lens rotating the drum to find the diopter power, then do the same procedure with the left lens.
Visual acuity	HOTV	It's based on an electronic tester (EVA) to identify each optotype found individually in a monocular manner, starting at 1 m and then at 3 m. If the patient correctly identifies 3 of the 4 charts, he or she passes the test. After completing the cycloplegic retinoscopy, test visual acuity again.
Stereopsis	Stereo Smile II	It has 1 demonstration plate (a smiling face), 1 blank plate and 3 plates of finer levels of stereopsis. If the child correctly identifies the demo plate 4 out of 4 or 4 out of 5 times, show him the blank plate matched with the plates of greater disparity.
Motility	Cover-uncover	Testing distance is 3 m and 40 cm. The child must observe a standardized target fixation. The examiner places a pallet over the child's left eye for 3 seconds to determine if reattachment occurs.
	Ductions and versions	With a transilluminator 30 cm away from the children in primary gaze position, move right, left, up, and down until the eyes are no longer able to continue.
Refraction	Cycloplegic and static retinoscopy	A retinoscope and portable lenses are used. The 2 main meridians of each eye are neutralized, and the child must fix on an animated objective in far vision. The anterior chamber is evaluated and retinoscopy is performed under cycloplegia.

Source: Donahue et al. (9), Vision in Preschoolers Study Group (26) and Arnold & Miller (42).

It was the first study to assess the sensitivity and specificity of each test, protocol and reproducibility according to the expertise of examiners, and so far it remains the most used benchmark in this type of research. The results of each test's sensitivity for detecting significant refractive error were good, with a specificity of 94%. For detection of reduced visual acuity, all tests had a sensitivity of less than 50%, which is a disadvantage for the protocol, since this data indicates that a low sensitivity produces loss of cases that could be treated (27). The results of the VIP study provide important information to guide the development and implementation of effective screening protocols.

This protocol is based on comprehensive tests that are well established, since they contain traditional methods that have been recommended by state organizations (12) and the medical community specializing in the subject of visual examination of school children. The HOTV visual acuity test has been used in children between the ages of 5 and 8 and validated in the studies by the VIP group; however, their sensitivity is somewhat lower compared with Lea Symbols charts applied to this same age group; the method used is also based on the use of technological tests composed by a special visual acuity screen, where the economic factor plays a limiting role in the access to it, since not all populations have the purchasing power to use this element in visual screening protocols.

Similarly, a low sensitivity in the cover test and non-cycloplegic retinoscopy for detecting ocular disorders is evidenced, and the stereopsis test showed a greater but not statistically significant sensitivity, indicating that, although the test is performed under standardized and controlled conditions, the quality of the evidence is not the best. Moreover, since the gold standard for the visual assessment in children not only includes tests to determine the presence of significant refractive error, but also detects amblyopia, strabismus and decreased visual acuity, which requires the use of more visual tests for correct diagnosis and in turn implies a greater length of time to obtain results, it becomes a very extensive protocol that is classified as complete examination. Thus, there are several aspects to be taken into account in the implementation of the protocol in the Latin American population because, although 22 % of the children in the VIP study were Latin people, this figure does not allow comparisons with the current reality in Latin America due to cultural differences with the United States, and therefore it is necessary to conduct research to validate the protocol in our population.

REFRACTIVE ERROR STUDY IN CHILDREN (RESC) (FULL EXAMINATION)

This study was designed to evaluate the prevalence of refractive error and visual impairment in children (5-15 years old) from different ethnic backgrounds and cultural settings. Over the past decade, a series of studies were conducted using this methodology, which confirmed that the prevalence of uncorrected errors of refraction is considerably high for children from low- and middle-income families, thereby determining that the uncorrected refractive errors are the second cause of blindness and the first cause of low vision in the world (43,44).

The design of this protocol ensures that the specific prevalence of age refractive error can be estimated with reasonable accuracy in target populations because it includes standardized measurements (43). The protocol consists in the evaluation of visual acuity from a distance of 4 meters with a directional E chart in LogMAR regression with five letters in each line, and the binocular motor function is evaluated (Hirschberg and cover test in far and near vision). The examination of the anterior segment (eyelids, conjunctiva, cornea, iris, and pupil) is performed in children with less than 20/40 visual acuity, and pupil dilation is required. The best corrected visual acuity is determined by the subjective, using the data of refraction. Finally, ophalmoscopy is performed with ocular biometry (measurement of the axial length and depth of the anterior chamber) (Table 5) (45).

TABLE 5. **Characteristics of the RESC protocol for visual assessment in children**

Test	Instrument	Technique
Visual acuity	Directional E chart	It starts at 4 meters, evaluating line 20/200 of visual acuity, where, if the patient reads four or more letters correctly, a visual acuity of 20/100 is evaluated. Otherwise, continue with line 20/50, then with line 20/25 and finally evaluate line 20/20. If at any level the patient fails to recognize at least four letters, try to evaluate a line above that. If the child is not able to identify the largest letter at 4 meters, the child will move to 1 m, performing the same process. The lowest line successfully read is assigned as the visual acuity for the eye under examination. Acuity with glasses is measured first, followed by measurement of uncorrected vision.
Binocular function	Cover test	It is performed without glasses. Hirschberg is determined first, then the cover test in far vision and near vision. Any corrective movement is detected while the child focuses an accommodative target in the distance required with both eyes open; if there is strabismus, it should be classified and neutralized with prisms.
External review	Magnifying glass and flashlight	You must register the abnormalities found in the eyelids, conjunctiva, cornea, iris, pupil, and anterior chamber depth as documentary evidence.
Refraction	Cycloplegic retinoscopy	Pupillary dilation is performed in children with visual acuity of less than 20/40 with 1 drop of topical anesthetic in both eyes, and two instillations of cyclopentolate at 1 % are performed every 5 minutes. After 20min refraction is performed with an Auto refractometer (you must obtain 5 readings with good levels of reliability) or by retinoscopy (at a distance of 0.75 meters and a lens +1.50). The power necessary to neutralize the movement of the shadow is observed.
	Subjective	The best corrected visual acuity is determined by the subjective, using the data of refraction.
Fundus	Direct ophthalmoscopy	It is performed in children with visual acuity of less than 20/40. The lens, vitreous and retina are assessed, and abnormal findings are recorded.
Biometry	Biometer	Axial length, anterior chamber depth, lens thickness and vitreous chamber depth are measured by scanning. A drop of local anesthetic is instilled in each eye. After 2 minutes of reading, start checking that the adjustments are set to display PHAKIC and AXIAL 1550 m/s. Five readings should be obtained within one standard deviation (SD) of 0.12 mm.

Source: Resnikoff (45).

The results reported with this protocol provide reliable and accurate data accepted by the American Academy of Ophthalmology, which gives validity to the studies published in different countries like South Africa, China, India, Brazil, and Saudi Arabia (44). In developing countries, access to eye care professionals is limited (46), and therefore the protocols for detection of refractive errors are not carried out. As a result, it is essential to train nurses and health workers who can perform the detection and send them to the affected population; however, there are tests in this protocol that can only be performed by ophthalmologists, which creates disadvantages for execution.

Although it is a very complete protocol, one of its disadvantages is that it requires the instillation of cycloplegic drops (cyclopentolate), which can only be performed by ophthalmologists or optometrists that are supported by the law 372 of 1997 (47), noting that, in Latin America, only Colombian optometrists can perform this type of activity. This limits the protocol's development in other countries even further, due to the difficulty in human resources, given that the costs generated by the need of an ophthalmologist are high, depending on the time of service, and that it involves funding for implementation. Similarly, the protocol requires the use of specialized equipment: an auto refractor and biometer, which are not easily accessible for performing of visual screening.

RAPID ASSESSMENT OF REFRACTIVE ERRORS IN CHILDREN: VISUAL SCREENING

The Rapid Assessment of Refractive Errors in Children (RARESC) is a new cost-effective protocol that determines the prevalence of refractive errors in children in a fast, simple and less costly, because it is based on a non-invasive methodology that includes assessing pinhole visual acuity and the use of two lenses of different strengths (+1.00 and +2.00 D) that determine the refractive error of children between the ages of 5 and 15, classifying them into myopia, hyperopia or astigmatism (Table 6) (48). The main objective of the protocol is to evaluate a new, cost-effective method to determine the prevalence of visual impairment and refractive errors in school children. The main disadvantage is the lack of scientific evidence to support the accuracy of the test, seeing as, until now, no investigations have been published that report in their results the validity of the protocol in terms of sensitivity and specificity.

IBERO-AMERICAN EPIDEMIOLOGICAL NETWORK IN VISUAL AND OCULAR HEALTH: FULL EXAMINATION

The Epidemiological Network for Visual and Ocular Health (REISVO), directed by La Salle

TABLE 6. **Characteristics of the RARESC protocol for visual assessment in children**

Test	Instrument	Technique
Visual acuity	Directional E chart +2.00 D lens	It starts with the assessment of visual acuity in the 20/30 line at a distance of 3 m. If the line is read correctly, place a +2.00 D lens in front of the eye and assess vision along the lines of 20/80. If the child passes the test, he is classified as farsighted and if he fails, he is classified as an emmetrope.
	Pinhole +1.00 D lens	If the child fails to read the 20/30 line, the pinhole is used and visual acuity in the 20/30 line is re-evaluated. If the child reads the line properly, a +1.00 D lens is prepended and the same line is evaluated again. If the child passes, he is classified as farsighted and if he fails, as myopic.
Ophthalmoscopy	Direct ophthalmoscopy	If the child fails to read the 20/30 line with a pinhole, direct ophthalmoscopy is performed, and if the fundus is normal, he is classified as amblyopic.

Source: Naidoo (48).

University in Colombia, promotes research in this area through knowledge transfer, establishing effective strategies for preventing blindness and low vision by designing and developing applicable epidemiological programs with scientific validity in the Latin American population (50). This protocol includes a visual acuity test (ETDRS), color vision testing made easy (CVTME), vision depth (Randot 2), refractive state (static retinoscopy), and oculomotor state (cover test) for children between the ages of 5 and 14 (Table 7).

For the visual acuity test, the ETDRS chart achieved good repeatability and reproducibility rates according to levels of significance, which for the Kendall correlation coefficient were found to be between 0.777 and 0.845, taking into account their classification (0.61 to –0.80 being good and 0.81 to 1.0 being very good) to assess the inter-examiner correlation on three separate days for both eyes. These results show that the difference between measurements was not statistically significant, leading to the conclusion that this test is repeatable and reproducible (52).

In the CVTME test, the intra-examiner concordance (kappa index) was 1.0 in the three measurements; the rates repeatability and reproducibility of test Randot 2 were between 20 and 50 arcseconds, with a close difference of less than 10 %, which shows good precision in the test, but not accuracy (51).

This protocol contains valid and accurate tests with an appropriate level of standardization for children between 5 and 15 years of age, with a degree of complexity from low to moderate, which makes it easier for the child to understand the test. The tests are easily implemented and charts are affordable for healthcare professionals. REISVO is based on epidemiological models that detect the status of the visual and ocular health of the Latin American population, and they have conducted research in countries like Colombia, Argentina, Panama, Costa Rica, Ecuador, Mexico, and Spain that reveal the applicability of the protocol for economic and social reality of Latin America, becoming a benchmark for vision screening. However, one of its disadvantages is that the execution time of the tests is extensive, which could generate little collaboration on the patient's part. In addition, the test used to evaluate the refractive state (static retinoscopy) is not adequate for this age group, since having no control over accommodation could overestimate the true refractive error data in myopic patients (50-52).

TABLE 7. **Characteristics of the REISVO protocol for visual assessment in children**

Test	Instrument	Technique
Visual acuity (50)	ETDRS	Start by evaluating the 20/200 line; ask the child to read letter by letter. The child is right if he reads 4 or 5 letters correctly. Move to the fourth line (20/100), continue with the seventh (20/50), and if the child reads correctly, evaluate line 20/25. Continue with line 11 (20/20), and if he is able to read it, move to line 12 (20/15). If the child is not able to read the biggest letter from a distance of 4 meters, bring the chart to a distance of 1 m, following the procedure explained above.
Color vision (51)	Color vision testing made easy	Place the reading desk on the auxiliary table with a 45° inclination of the chart; sit the child 75 cm away from the chart with the usual correction, occlude the left eye, present the demonstration sheet and ask which figure appears in it. After the child understands, show the sheets one by one and register the answers.
Stereopsis (51)	Randot 2	Sit the child at a distance of 40 cm, wearing polarized glasses; the child should look at the four upper boxes and then at the lower ones on the right page of the chart. Ask the child to observe the rectangles with the animals in the lower left and to identify which animal stands out in each one; then, ask the child to observe the rectangles with the rings. Suspend the test if he makes two consecutive errors.
Refraction (35)	Static retinoscopy	The child should look at the first line of the chart (20/200) from a distance of 6 m, while the examiner is located at a distance of 50 cm with the retinoscope; +2.00 lenses are placed in front of both eyes to compensate for the working distance, and the movement of the shadows in the meridians is observed and neutralized with lenses; the process is repeated with the other eye.
State motor (52)	Cover test	Check central locking, place the HOTV chart at a distance of 3 m fixating on a line of less than the best visual acuity with optical correction. Completely occlude the patient's eye for 3 seconds and observe if movement occurs in the other eye, repeating the procedure three times. Determine the type of offset and neutralize with prisms, the same procedure is performed for near vision.

Given the above, and according to the analysis of vision screening protocols currently employed, it is important to note that, being created by Ibero-American people, the REISVO protocol can be applied to our economic and social context, noting that research has been conducted in Colombia serving to demonstrate their applicability to our cultural reality. Also this protocol uses specific tests that are not covered by others, such as viewing depth (Randot 2), which assesses the transmission of information independently, considering that stereopsis is the most important function of binocular coordination, providing valuable data when identifying visual disorders such as amblyopia, strabismus and uncorrected refractive error. However, the only disadvantage is the use of static retinoscopy for the refractive evaluation of the child, which could be replaced by dynamic retinoscopy and in this way control the patient's accommodation and obtain reliable results.

Like REISVO, the VIP protocol uses a stereopsis test (Stereo Smile II) for determining whether there is binocular vision, and it includes tests for assessing color vision, which is an essential aspect of visual perception. However, the test used requires a higher level of cognitive ability, and therefore its application in school-age children can be hindered; as a result, it is necessary to apply simple screening tests in our daily practice to replace testing by pseudoisocromatical sheets specializing in pediatric assessment (Color Vision Testing Made Easy), which reduces the test time with the rapid response of the child thanks to the low complexity of the figures used. Likewise, with the aim of reducing the time of implementation of the protocol, the evaluation of motor function is not necessary unless the cover test is altered. It would also be interesting to include the dynamic retinoscopy as a substitution to the static and cycloplegic retinoscopy, where the latter is only applied when there are alterations in the accommodation that prevent obtaining the real data of the refractive error.

Finally, the RESC protocol has been used worldwide, and therefore its results are repeatable and reproducible, because their measurements are standardized by the quality of their evidence, providing validity to test employees. However, as mentioned above, its biggest disadvantage is the use of cycloplegic drops, which, when applied as full examination protocol, limits their use in practice, increasing the time spent in execution; therefore, the auto refractometer could continue to be used, but without using cycloplegic drops, thus preventing anterior segment scan to check the angle of the anterior chamber and optimizing the time in carrying out the protocol, plus reducing costs in the use of drugs and trained staff to develop this activity. Similarly, they can be ruled out as unnecessary ocular biometry tests in order for the protocol to be cost effective and to be employed in optometry to detect refractive errors in children.

CONCLUSIONS

The review shows that the early detection of refractive errors through visual screening in school-age children allows an adequate intervention, taking into account that, in this population, the development and maturation of the visual system is fast and requires adequate stimuli to avoid appearance of visual disorders.

In overall terms, the visual screening conditions in schools are varied and depend on sociocultural factors for implementing the tests, and it is important to validate the test according to the population where they will be run.

The protocols currently used in epidemiological studies in the world for detection of refractive errors in children have several advantages. However, it is necessary to consider some modifications, such as the use of dynamic retinoscopy instead of cycloplegic retinoscopy, exclusion of cycloplegic drops when using auto refractometers, and the elimination of some tests such as ocular biometry in order to optimize and improve its structure, facilitate their implementation in our daily practice, and obtain better results depending on the quality of the evidence.

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