Screening for abnormal levels of hyperopia in children: a non-cycloplegic method with a hand held refractor

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Abstract

Aims—High hyperopia constitutes the majority of refractive errors in large scale visual screening at preschool ages. The authors aimed to assess the validity of the Retinomax hand held refractor to detect high hyperopia in a refractive screening performed without cycloplegia and carried out on children aged 9–36 months. They considered +1.5 D of manifest hyperopia to be the threshold value and abnormal absolute hyperopia to be above +3.5 D.

Methods—Of the 897 children screened without cycloplegia, 220 were refracted with cycloplegia. The validity of several thresholds of manifest hyperopia was estimated by receiver operating characteristic (ROC) curves using cycloplegic measures as a reference. The reproducibility of Retinomax measurements was assessed. Normal and quick mode measurements were compared using the Wilcoxon test.

Results—The manifest threshold of +1.5 D offered the best combination of sensitivity (70.2%), specificity (94.6%), positive predictive value (78.6%), and negative predictive value (91.9%) to disclose abnormal absolute hyperopia. A good agreement was obtained between the various measurements using Retinomax on the same subject. In the results of this survey, there is no evidence that accommodation is minimised in the normal mode of measurement compared with the quick mode.

Conclusion—The Retinomax hand held infrared autorefractor is a suitable instrument to diagnose abnormal hyperopia (manifest hyperopia >+1.5 D) in non-cycloplegic refractive screening at preschool ages. It is suggested as the quick mode of measurement as it is more feasible in children (success rate 98.5%).

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Amblyopia is the main cause of visual defects in children.[1] Recent research tends to demonstrate that refractive anomalies are the leading cause of amblyopia.[2][3] Refractive screening therefore constitutes an integral part of several large scale visual testing programmes in preschool children.[4–10] Among them, the Cambridge photoscreening programme[10] shows that an abnormal level of hyperopia (over +3.5 D in one or more meridians) is the most frequent refractive anomaly (5–6%) found in a population at 9 months of age. It is associated with a higher risk of amblyopia (37.5% versus 5.6% in the control group) and strabismus (21% versus 1.6%) at 4 years of age.

This high prevalence of abnormal hyperopia together with its increased risk of amblyopia and strabismus implies that refractive screening should detect it with good sensitivity and specificity rates, preferably without cycloplegia. Cycloplegia is indeed time and energy consuming and, as an invasive act, is not suitable for a screening procedure. Cycloplegia could be avoided if there was a manifest (non-cycloplegic) hyperopia threshold leading, with reasonably good sensitivity and specificity, to an absolute (cycloplegic) hyperopia greater than + 3.5 D. Atkinson *et al*[10] have already promoted non-cycloplegic videorefractive screening, choosing an accommodative lag of ≥ 1.5 D as a good predictor of hyperopic refractive errors under cycloplegia.

We tried to determine if such a threshold could be found and validated with the hand held infrared automated refractor, Retinomax (Nikon Inc, Japan) in a sample of children aged 9–36 months.

Material

RETINOMAX HAND HELD REFRACTOR

Description

This automated hand held refractor (Fig 1) appeared on the market in autumn 1995. Its measurement range is within −18/+22 D for spheres and 8 D for cylinders. The minimal required pupillary diameter is 2.7 mm. Information regarding technical specifications and optical principles is sparse in the operator manual. The Nikon Ophthalmic Division newspaper reports similar principles for the Nikon NR-1000 F autorefractor and Retinomax—infrared light is used, the principle of retinoscopy is applied in the illumination system, and the Scheiner principle in the detection system. Neutralisation of the retinoscopic reflex is not performed, but rather the speed of the reflex is determined in each meridian as the instrument sweeps through 360° very quickly.[11] An infrared light sensitive camera allows the operator to visualise the measured eye on a screen. The operator aligns the instrument on reflected light from the child's cornea, with the child looking at a Christmas tree on a green grass and blue sky background. In the normal mode of measurement, as soon as adequate alignment is

Figure 1 Measuring refraction with the Retinomax.

obtained, the fixation target is automatically fogged to minimise accommodation. If the child is moving too much, a "quick" mode disables the fogging system and allows measurement to begin immediately. This can sometimes lead to aberrant values if the eye is not fixating properly.

The instrument takes N number of measurements successively on both eyes, prints a maximum of the eight last measurements and displays an isolated representative value for each eye. N/2+1 from the smallest measurement is the representative value. If N/2 has decimals, they are omitted. If N is an odd number the representative value is thus the median value for sphere, cylinder, and axis. If there are eight values, the representative value will be the fifth smallest value.

One measurement takes 5/1000th of a second and is displayed in 0.2 seconds. In the quick mode, approximately 10 seconds are needed to start measuring and have 16 values for both eyes. With the normal mode, at least 15 seconds are necessary (more if the eyes are not properly aligned).

Accuracy

Kallay *et al*[12] have compared cycloplegic refraction values obtained with the Retinomax and with Topcon 6000 "on table" automated refractor. They obtained good agreement between the two refractors.

Wagner *et al* [13] found that agreement between retinoscopy and Retinomax measurements was comparable with agreement between repeated measurements obtained by retinoscopy, subjective refraction, or autorefraction.

How to handle Retinomax

Retinomax is an easy to handle instrument (minimal experience is required), less frightening to young children than on table automated refractors. As there is no chin rest, the head stays free. The target is attractive (Christmas tree). If the child is reluctant and moves the Retinomax aside with his hands while sitting on his mother's knee (15%), she can gently hold his hands with one arm and steady his

head with the other to permit measurement. In cases of extreme opposition, the child can be restrained on a couch which helps to steady his head (one person) and body (another person). If there is only one person, or if the parents do not allow their child to be forcibly steadied, failure to take measurement can occur (1.5%). Once the eye is aligned, pressing a button triggers an automatic collection of eight measurements of the first eye, a buzz warns the operator that he can switch to the other eye and another eight measurements are automatically taken again. It is important to watch the eye behaviour carefully on the screen. The quality of the image is similar to that of the on table automated refractor. In case of media opacity, the instrument is unable to give a measurement. Instrumental myopia happens frequently initially and it is important to wait for *the more positive and stable values* before halting the measurement process. Only the eight last measurements will be printed. Since the process of measurement is quick and simple, repetition of measurements is easy to perform in doubtful cases.

Population and methods

Since November 1995, we have organised free visual screening for children aged 9–36 months at our university hospital situated in Brussels. This screening was conducted by an orthoptist, and given to any child whose parents were willing for him to undergo it. Screening sessions took place twice a week, on a phone appointment basis. Information regarding the screening had been distributed by paediatricians and nurseries by means of an informative leaflet.

The child was sent to an ophthalmologist outside the hospital if he had abnormal manifest or absolute refraction, a squint, or any other disabling eye condition.

Among other tests, this visual screening required:

● a measurement of manifest refraction with the Retinomax autorefractometer
● a near cover test

The refractive values corresponded to the isolated representative value of the eight collected measurements for each eye, expressed in sphere, negative cylinder, and axis. The use of normal or quick mode was registered. As all cylinders were negative, the more hyperopic meridian was expressed by the sphere. Whenever measurement had been repeated, we chose the most positive representative value, in order to minimise accommodation.

Our criteria for abnormal manifest refraction were:

● hyperopia >+1.5 D
● myopia >−3 D
● astigmatism ⩾4 D whatever the age of the child, ⩾2 D if the child was above 2 years old
● spherical or cylindric anisometropia ⩾3 D whatever the age of the child, ⩾1.5 D if the child was above 2 years old

If the child had one or more criteria of abnormal refraction and/or a squint, and if the parents consented, one of the authors (MC)
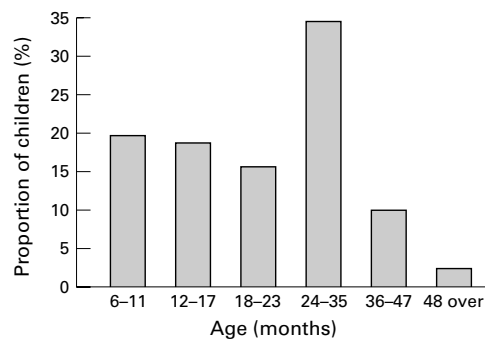
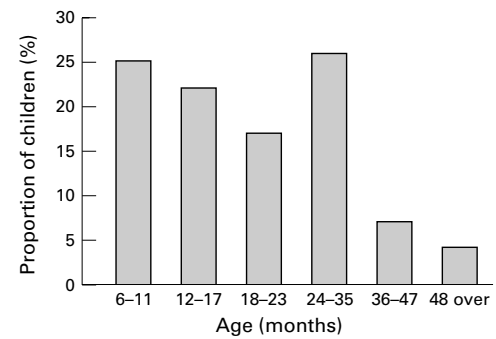*Figure 2   Age distribution of the 897 screened children.*

Figure 3   Age distribution of the 220 children with cycloplegia.

performed a cycloplegic refraction during the same session before referring the child to an ophthalmologist (three drops of cyclopentolate 0.5% in each eye at 5 minute intervals followed by measurement 40 minutes later). For deontological reasons, considering the fact that the screening was free, no child attending the screening could be referred to an ophthalmologist appointed by the hospital.

Under cycloplegia, the same criteria of abnormal refraction applied except hyperopia +3.5 D.

We screened 897 children aged 6 months to 5 years (mean 23.5 (SD 11.1) months) comprising 492 boys and 405 girls. Among them, 83.5% had the intended screening age (9–36 months). Figure 2 shows the distribution of age of these children.

A failure to measure refraction happened in 1.5% of the 897 cases (see how to handle Retinomax); 642 children had one measurement only, 234 had two measurements, and 21 had three measurements without cycloplegia.

To analyse the agreement between measurements, we determined the mean difference of sphere between the first and second measurements. This mean difference was 0.093 (1.398) and 0.083 (1.244) for the right and the left eye respectively.

Two hundred and two children (22.5%) corresponded to our criteria of abnormal manifest refraction and/or squint. A cycloplegic refraction was performed on 72 (35.6%) children.

Six hundred and ninety five (77.5%) children had neither refractive anomalies nor squint. Among the total, 148 children (21.3%) were selected in a consecutive manner and labelled as controls. They had a fundus examination and were refracted under cycloplegia by MC, during the same session. Thus, a total of 220 children had cycloplegic refractive measurement. Their age distribution is shown in Figure 3.

The first question in this study was to see if there was a real difference between manifest refraction in the normal or the quick mode. Both modes of measurement were compared using the Wilcoxon non-parametric test for sphere, cylinder, and axis. On the basis of the results of this test, we decided to present subsequent analyses with measurements made entirely in normal or quick mode. The proportion of quick mode measurements in the following analyses is 72%.

The second and main question was to determine whether the manifest refraction threshold of +1.5 D (positive test) of hyperopia was valid to disclose an absolute hyperopia of +3.5 D (true positive case). If not, could another better threshold be found?

To validate threshold, receiver operating characteristic (ROC) curves were estimated using cycloplegic measures as reference in 215 out of the 220 children (four children having an absolute myopia above −3 D and one child having a measurement on the left eye only were excluded). The ROC curve is obtained by plotting the proportion of true positives or the sensitivity of a diagnostic test (proportion of positive tests among the true positive cases) against the proportion of false positives (proportion of positive tests among the true negative cases); these two factors being estimated at different operating points of manifest hyperopia. The performance of a diagnostic test may be evaluated by the area under the ROC curve. The diagonal of the graph is called the "chance line" as its points correspond to equal proportions of false and true positives. If the ROC curve of a test follows approximately the chance line, the test is diagnostic no better than random and the area under the curve is around 0.5. The better the performance of a diagnostic test in terms of sensitivity and specificity, the higher the ROC curve above the diagonal and the closer to 1 is the area of the curve. ROC curves and their areas were obtained with the Metz Fortran program.[14 15]

Once the threshold was validated, a child was considered hyperopic if one or both eyes were above the threshold of manifest refraction.

Finally, we considered the frequency of hyperopia in our sample, the age and sex distribution, and the type of associated astigmatism in abnormal hyperopia ("with the rule" astigmatism if negative cylinder below 30° or above 150°, "against the rule" astigmatism if negative cylinder between 60° and 120°).

Results

ABOUT QUICK AND NORMAL MODE

Eighty six children had their manifest refraction performed with both quick and normal mode. No significant differences were observed, except for the spheres of the right eye (p=0.047): the median right spheres under

Table 1   Rates of sensitivity, specificity, positive and negative predictive values for different thresholds of manifest hyperopia

Threshold of manifest hyperopia	Positive test No (%)	Negative test No (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
> +1.00	72 (33.5)	143 (66.5)	78.7	79.2	51.4	93.0
> +1.25	58 (27.0)	157 (73.0)	72.3	85.7	58.6	91.7
> +1.50	42 (19.5)	173 (80.5)	70.2	94.6	78.6	91.9

PPV = positive predictive value, NPV = negative predictive value.
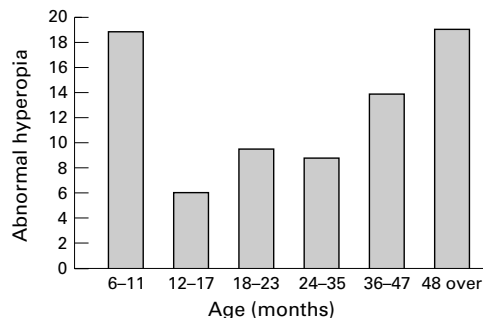
Figure 4   Age distribution of abnormal hyperopia.

quick mode and normal mode were 0.250 and 0.125 respectively.

CONCERNING THE MANIFEST HYPEROPIA THRESHOLD

The surface area index of the ROC curves is 0.79 (0.05) for the right eye and 0.82 (0.04) for the left eye indicating that manifest hyperopia is a good diagnostic test to predict absolute hyperopia +3.5 D. Good sensitivity and specificity are found at thresholds of manifest hyperopia >+1, >+1.25, and >+1.5 D. Below or equal to +1 D, specificity decreases under 70% and above +1.75 D, sensitivity decreases around 62%.

Table 1 shows the rates of sensitivity, specificity, positive and negative predictive values for different thresholds of manifest hyperopia.

TYPE OF ASTIGMATISM MOST FREQUENTLY FOUND IN HIGH HYPEROPIA

We found that, when associated with abnormal hyperopia, significant astigmatism (⩾2 D) appeared to be "with the rule" in 90% of our cases.

FREQUENCY, SEX RATIO, AND AGE DISTRIBUTION OF ABNORMAL HYPEROPIA IN OUR POPULATION

Taking into account the threshold +1.5 D of manifest hyperopia, the frequency of abnormal hyperopia is 11% in our population. There were no sex differences. The age distribution is plotted in Figure 4. The proportions of abnormal hyperopia differ significantly between age groups.

Discussion

AGREEMENT BETWEEN SEVERAL MEASUREMENTS IN THE SAME CHILD

The mean difference of two successive measurements in the same child is very close to zero for both eyes, showing good agreement, but the standard deviation is high because in 10% individuals the difference between two successive measures is higher than 2 D.

This emphasises the need to wait for the most stable and positive measurements before halting the measurement process and to consider the most positive representative value. It is not uncommon to see −4 D of myopia at the beginning of the measurement process which then tapers down to levels around −0.5 D. In doubtful cases, it is better to repeat the measurements.

ABOUT THE NORMAL AND QUICK MODE

Normal mode makes measurements longer and more difficult (and sometimes impossible) in very young children; quick mode measurements are much more easy to obtain and almost always successful in our hands. However, should normal mode really attenuate accommodation, it would be worth choosing this mode rather than the quick mode.

Now, the only significant difference in Wilcoxon non-parametric tests found for the right sphere is not clinically important and shows more positive results for quick mode, refuting any attenuation of accommodation in normal mode in our population. We therefore suggest choosing the quick mode for screening children of this age.

THRESHOLD CHOICE OF +1.5 D MANIFEST HYPEROPIA

Considering the different figures expressed in Table 1, the threshold of +1.5 D offers the best combination: there is a slight decrease of sensitivity compared with threshold +1 D (70.2% instead of 78.7%) but the specificity is much better (94.6% instead of 79.2%), leading to a better positive predictive value (78.6% instead of 51.4%). The low screening yield of amblyopia or its risk factors demands high specificity rates in order to reach a good positive predictive value.[16][17] For validating our visual screening, and as hyperopia is not a severely disabling eye condition, we preferred a highly specific test to avoid overreferrals.[18] Therefore, we kept the threshold of >+1.5 D for the ongoing screening.

With VPR-1 videorefractor and a similar manifest threshold of +1.5 D, Anker *et al*[19] have a slightly worse figure of positive predictive value (73%) and a better figure of negative predictive value (97%). Compared with VPR-1 videorefractor, Retinomax offers the advantages of an easy to handle instrument and compact enough to allow ambulatory screening. It is also less expensive: the VPR-1 videorefractor costs approximately £10 000[20] and the Retinomax £7000.

FREQUENCY OF REFRACTION ANOMALIES AND SQUINT IN THE POPULATION

In all, 22.5% of the children corresponded to our criteria of abnormal manifest refraction and/or squint; 34 (3.8%) children had both refractive anomalies and squint, 125 (13.9%) had refractive anomalies only, and 43 (4.8%) had strabismus only. Abnormal hyperopia was found in 11% of our population. These figures are higher than those found in the literature.[2][3][5][9][10] The reason is that our screening is made on an appointment basis and not

on a captive population (for example, screening children at school). It follows that a selection bias was present in the population we screened: among others, we selected many children with a family history of strabismus or amblyopia and also children having a visual anomaly suspected by their parents or paediatrician.

TYPE OF ASSOCIATED ASTIGMATISM

In our results, the majority of astigmatisms associated with abnormal hyperopia is with the rule. Ehrlich *et al* [21] reached the same conclusion in the population of high hyperopia screened by Atkinson *et al*.[10]

AGE DISTRIBUTION OF ABNORMAL HYPEROPIA

The age distribution shows a considerable level of abnormal hyperopia before 12 months of age. According to Saunders[22] considerable numbers of refractive error may exist before 1 year of age and disappear later owing to the emmetropisation process. After 12 months, the frequency is much lower and then rises again. We feel that the increasing proportion of abnormal hyperopia found in the older groups reflects the selection bias of our screening.

Conclusion

Our results show that the Retinomax hand held infrared autorefractor is a suitable instrument to diagnose abnormal hyperopia in non-cycloplegic refractive screening at preschool ages. We suggest choosing the threshold of abnormal manifest hyperopia at >+1.5 D because it offers the best positive predictive value. As the quick mode of measurement is more feasible in children and as we did not establish less accommodation with the normal mode we also suggest choosing this mode of measurement. This makes the procedure of refraction sufficiently fast that the success rate of taking measurements is high. In our study, it reached 98.5% of all the children attending the screening, whatever their age.

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