Diagnosis and Management of Refractive Error in Infants & Young Children
A Current Perspective

Susan A. Cotter, OD, MS, FAAO
SCCO at Marshall B Ketchum University

Tawna L. Roberts, OD, PhD, FAAO
Akron Children’s Hospital
Disclosures

• Commercial: None

• Research funding: EY14472 (SAC), K23EY022357 (TLR)
Course Objectives

1. Tips for Diagnosis
2. Emmetropization & Normal Refractive Error
3. Hyperopia & Risk of Esotropia
4. Hyperopia & Risk of Amblyopia

5. Associated Refractive Errors
6. Accommodation
7. Hyperopia and Academic Performance
8. Symptoms & Other Clinical Findings
Pediatric Eye Examination
Pediatric Eye Examination: Minimum Database

- Stereopsis
- Cover Testing
- Visual Acuity
- Refraction
- Ocular Health
Fixation Targets – You Can’t Have Too Many
Stereopsis Testing

RDS: No monocular cues; typically must have bifoveal fixation
RDS Stereotests
Titmus Stereotest (Fly)
Cover Test at Near

Use Accommodative Target & Stress Clarity
Prism & Alternate Cover Test at Near
Hirschberg Testing
Hirschberg Testing
Krimsky Test
Preschool VA Test: Desirable Characteristics

- High contrast, single, surrounded optotypes
  - LEA or HOTV optotypes
- Verbal or directional response not necessary
- LogMAR progression
- Reduced (3 meter) test distance
- 2-alternative forced choice or matching

LEA Symbols

HOTV
To Cycloplege or Not to Cycloplege?
Cycloplegic Refraction Regimen

- Topical anesthetic (usually)
- 2 gtts cyclopentolate
  - 1% for children ≥1 year
  - 0.5% for children <1 year
- Phenylephrine or tropicamide for mydriasis
- Wait 30 minutes
Pediatric Eye Examination: Minimum Database

- Stereopsis
- Cover Testing
- Visual Acuity
- Refraction
- Ocular Health
Considerations When Prescribing for Hyperopia
How Often Are Spectacles Prescribed for “Normal” Preschool Children?

Study: Not all kids with glasses need them

Many will outgrow mild farsightedness

By Liz Szabo
USA TODAY

A study released today finds that up to 25% of children with normal eyes who have comprehensive vision exams may be prescribed glasses they don’t need.

In an article published online in the Journal of the American Association of Pediatric Ophthalmology and Strabismus, the researchers report that many children with normal vision may be prescribed glasses because the doctors who typically treat adults do not have as much experience with children.

Though many doctors recommend that preschoolers be screened for vision problems, experts disagree about the best approach. Kentucky requires that youngsters undergo comprehensive eye exams before beginning school.

35% (OD) vs. 6% (MD)*
For kids without amblyogenic factors or pathology

*Peds Ophthalmol =2%

### Table 3: Guidelines for Prescribing Eyeglasses for Young Children

<table>
<thead>
<tr>
<th>Condition</th>
<th>Age 0–1 year</th>
<th>Age 1–2 years</th>
<th>Age 2–3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Isometropia</strong> (similar refractive error in both eyes)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myopia</td>
<td>≥−4.00</td>
<td>≥−4.00</td>
<td>≥−3.00</td>
</tr>
<tr>
<td>Hyperopia (no manifest deviation)*</td>
<td>≥+6.00</td>
<td>≥+5.00</td>
<td>≥+4.50</td>
</tr>
<tr>
<td>Hyperopia with astigmatism†</td>
<td>&gt;+2.00</td>
<td>&gt;+2.00</td>
<td>&gt;+1.50</td>
</tr>
<tr>
<td>Astigmatism‡</td>
<td>≥3.00</td>
<td>≥2.50</td>
<td>&gt;2.00</td>
</tr>
<tr>
<td><strong>Anisometropia</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myopia</td>
<td>≥−2.50</td>
<td>≥−2.50</td>
<td>≥−2.00</td>
</tr>
<tr>
<td>Hyperopia</td>
<td>≥+2.50</td>
<td>≥+2.00</td>
<td>≥+1.50</td>
</tr>
<tr>
<td>Astigmatism‡</td>
<td>≥2.50</td>
<td>≥2.00</td>
<td>≥2.00</td>
</tr>
</tbody>
</table>

**Note:** These values were generated by consensus and are based solely on professional experience and clinical impressions, because there are no scientifically rigorous published data for guidance. The exact values are unknown and may differ among age groups; they are presented as general guidelines.

* May reduce the amount by up to +2.00 D, or if the cycloplegic prescription is ≥+7.00 D may reduce by up to +3.00 D.
† Give the full cycloplegic prescription. If ≥+3.00 D, may reduce by +0.50 D.
‡ Any oblique astigmatism (defined as ≥15° from the 90° or 180° axis) >1 D should be considered for treatment.

[http://www.aao.org/education/library/ppp/]
Hyperopia: Prescribing Considerations

- Magnitude:
  - Within normal range for age?
  - Expected to change with age?
  - Potentially amblyogenic?
  - Risk factor for ET?
  - Visual demands
Hyperopia: Prescribing Considerations

- Other clinical examination findings?
  - Visual acuity
  - Phoria (direction & magnitude)
  - AC/A, stereo
  - Accommodative amplitude & lag
- Symptoms or signs?
- History: child (including meds) & family?
- Academic readiness / performance?
Strabismus +/- or Amblyopia Present

Prescribing Guidelines
Goals: provide equally clear retinal images & improve eye alignment

- Full anisometropia / astigmatism / myopia
- Full (or close to full) plus for ET’s
- (Typically) least plus for XT’s
- If reduce hyperopia, cut symmetrically
Emmetropization – What Do We Know?
Emmetropization

Mutti DO, Zadnik K., 1997. (Cook & Glasscock, 1951 and unpublished data from Orinda Longitudinal Study of Myopia)
Emmetropization

Mutti, DO. Optom Vis Sci 2007;84:97–102
Accommodative Lag, Uncorrected Hyperopia, and Emmetropization

Adapted from Mutti et al. Optom Vis Sci 2009; 86(6):666-676
Probability of Emmetropization Based on Refractive Error at 3 Months

Mutti et al. Optom Vis Sci 2009; 86; 666-76
What is Normal Refractive Error?
Normal Refractive Error

Spherical Equivalent (D)

Hispanic  African American  Non-Hispanic White  Asian

Percent (%)

6-11 months

60-72 months

 MEPEDS 2010, MEPEDS 2013
### Mean Refractive Error: MEPEDS

<table>
<thead>
<tr>
<th>Race/Ethnicity</th>
<th>Spherical Equivalent Mean Diopters (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>African American</strong></td>
<td>+1.0 (1.4)</td>
</tr>
<tr>
<td>(2992)</td>
<td></td>
</tr>
<tr>
<td><strong>Hispanic</strong></td>
<td>+1.2 (1.4)</td>
</tr>
<tr>
<td>(3000)</td>
<td></td>
</tr>
<tr>
<td><strong>NHW</strong>*</td>
<td>+1.3 (1.1)</td>
</tr>
<tr>
<td>(1486)</td>
<td></td>
</tr>
<tr>
<td><strong>Asian</strong>*</td>
<td>+0.8 (1.2)</td>
</tr>
<tr>
<td>(1507)</td>
<td></td>
</tr>
</tbody>
</table>
Uncorrected Hyperopia and the Risk of Esotropia
<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plano to &lt; +1.00D</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>+1.00 to &lt; +2.00D</td>
<td>1.8</td>
<td>0.7 to 4.6</td>
</tr>
<tr>
<td>+2.00 to &lt; +3.00D</td>
<td>6.4</td>
<td>2.6 to 16.0</td>
</tr>
<tr>
<td>+3.00 to &lt; +4.00D</td>
<td>23.1</td>
<td>9.6 to 55.6</td>
</tr>
<tr>
<td>+4.00 to &lt; +5.00D</td>
<td>59.8</td>
<td>23.6 to 151.5</td>
</tr>
<tr>
<td>+5.00 to &lt; +6.00D</td>
<td>122.4</td>
<td>50.0 to 300.0</td>
</tr>
</tbody>
</table>

Cotter et al, MEPEDS/BPEDS. Ophthalmology 2011;111:2251-2261
Prevalence of > +2.00 D SE

- Hispanic
- African American

- Non-Hispanic White
- Asian

MEPEDS. Ophthalmology 2010; 117:140-147, MEPEDS. Ophthalmology 2013;120:2109
Can You Prevent Esotropia by Correcting Hyperopia?
Spectacle correction versus no spectacles for prevention of strabismus in hyperopic children (Review)

Jones-Jordan L, Wang X, Scherer RW, Mutti DO

Spectacle correction versus no spectacles for prevention of strabismus in hyperopic children (Review)

Jones-Jordan L, Wang X, Scherer RW, Mutti DO

The true effect of spectacle correction before age 1 year for hyperopia for the prevention of strabismus is uncertain.

Will you inhibit emmetropization by prescribing for hyperopia?
Does Correcting Hyperopia at an Early Age, Adversely Affect Emmetropization?

Partial SRx did not affect emmetropization.

Bottom Line? Moderate Hyperopia in Youngsters

- Hyperopia (even as low as 2.00 D) IS a risk factor for ET
- Do NOT know if prescribing a full or partial prescription reduces the incidence of ET
- NO good evidence in humans that prescribing for hyperopia adversely affects emmetropization
Uncorrected Hyperopia & the Risk of Isoametropic Amblyopia?
## Amblyogenic Isoametropia

<table>
<thead>
<tr>
<th></th>
<th>CPG*</th>
<th>PPP**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astigmatism</td>
<td>&gt;2.50 D</td>
<td>≥2.00 – 3.00 D</td>
</tr>
<tr>
<td>Hyperopia</td>
<td>&gt;5.00 D</td>
<td>≥4.50 – 6.00 D</td>
</tr>
<tr>
<td>Myopia</td>
<td>&gt;8.00 D</td>
<td>≥3.00 – 5.00 D</td>
</tr>
</tbody>
</table>

*AOA Clinical Practice Guideline on Amblyopia; *not address age
**Preferred Practice Pattern on Amblyopia. AmAcadOphthalmology

Consensus opinion only; PPP lower magnitude ≥2 years
## Risk of Bilateral Decreased VA Associated with Hyperopia

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plano to &lt; +1.00D</td>
<td>Reference</td>
<td>0.37</td>
</tr>
<tr>
<td>+1.00 to &lt; +2.00D</td>
<td>0.37</td>
<td>0.13 – 1.02</td>
</tr>
<tr>
<td>+2.00 to &lt; +3.00D</td>
<td>1.02</td>
<td>0.36 – 2.85</td>
</tr>
<tr>
<td>+3.00 to &lt; +4.00D</td>
<td>1.64</td>
<td>0.51 – 5.24</td>
</tr>
<tr>
<td>&gt;+4.00D</td>
<td>11.45</td>
<td>5.01 – 26.18</td>
</tr>
</tbody>
</table>

MEPEDS/BPEDS: 5704 AA, Hispanic, White Children 30-72 months; Adjusted for age, astigmatism, gestational age. Level of hyperopia defined by least hyperopic eye.

How About Astigmatism & Anisometropia?
## Prevalence of >1.00 D Astigmatism

<table>
<thead>
<tr>
<th></th>
<th>3 months</th>
<th>36 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTR ≥ 1.00 D</td>
<td>n = 69 (37.7%)</td>
<td>n = 2 (1.1%)</td>
</tr>
<tr>
<td>WTR &lt; 1.00 D</td>
<td>n = 74 (40.4%)</td>
<td>n = 78 (42.6%)</td>
</tr>
<tr>
<td>None</td>
<td>n = 13 (7.1%)</td>
<td>n = 54 (29.5%)</td>
</tr>
<tr>
<td>ATR &lt; 1.00 D</td>
<td>n = 22 (12.0%)</td>
<td>n = 44 (24.0%)</td>
</tr>
<tr>
<td>ATR ≥ 1.00 D</td>
<td>n = 5 (2.7%)</td>
<td>n = 5 (2.7%)</td>
</tr>
</tbody>
</table>

96.1%

Mutti et al., Optom Vis Sci 2004; 81(10):753-761
## Risk of Decreased Unilateral VA Associated with Anisometropia

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.5 D</td>
<td>Reference</td>
<td>--------------</td>
</tr>
<tr>
<td>0.50 to &lt;1.00D</td>
<td>1.45</td>
<td>1.03 – 2.05</td>
</tr>
<tr>
<td>1.00 to &lt;2.00D</td>
<td>4.51</td>
<td>2.76 – 7.36</td>
</tr>
<tr>
<td>&gt;2.00D</td>
<td>39.04</td>
<td>19.24 – 79.21</td>
</tr>
</tbody>
</table>

MEPEDS/BPEDS: 5704 AA, Hispanic, & White Children 30-72 months
* IOD of ≥2 lines with 20/32 or worse in worse eye; Adjusted for age, strab, school attendance

Prevalence of Decreased VA by Anisometropia in Preschool Children
Considerations When Prescribing for Hyperopia
Prescribing Considerations

- Family History
- Symptoms
- Distance and near visual acuity
- Near stereopsis
- Accommodation
- Eye alignment and posture
- Academic or learning problems
Vision in Preschool – Hyperopia in Preschool Study

Visual Performance of 4- & 5-year-olds with Moderate Hyperopia

Emmetropia (<1.00 D ametropia) vs. Uncorrected Hyperopia (≥ +3.00 to ≤ +6.00 D)

- VA (Monoc Dist, Binoc Near)
- Accommodative Response
- Near Stereoacuity

P < 0.05

Significantly worse performance on TOPEL:
- $\geq +4.00$ D uncorrected hyperopia
- $\geq +3.00$ D to $\leq +6.00$ D uncorrected hyperopia and
  reduced near VA or reduced near stereo

Kulp et al., VIP-HIP, Ophthalmology 2016
Visual Performance of 4- & 5-year-olds with Moderate Hyperopia

Tests of Attention, Visual Motor Integration, & Visual Perception

- Found a relationship between moderate, uncorrected hyperopia with reduced visual function and deficits in measures of sustained attention, VMI, and visual perception

Kulp et al., VIP-HIP, Optom Vis Sci 2017; Vol94(10)
Effect of Spectacle Correction on Preschoolers’ Cognitive Abilities

• 3- to 5-years-old low income
• Previously uncorrected (n=35)
  – Bilateral hyperopia of ≥ +4.00D
  – Astigmatism ≥ 2D if 3yrs, ≥ 1.50 if 4-5 years
• Emmetropia (n=35)
  – Bilateral hyperopia <2D; <1D cyl OU
• Visual motor integration (VMI) & Wechsler Preschool & Primary Scale of Intelligence Revised (WPPSI-R)
  – Baseline
  – 6 wks post-SRx (full astigmatism; cut hyperopia 1.50-2.00D)

Roch-Levecq et al. Archives of Ophthalmology 2008;126;252-8
Effect of Spectacle Correction on Preschoolers’ Cognitive Abilities

• **Baseline**: Significantly reduced in hyperopes (vs. emmetropes)
  – VMI
  – Most WPPSI-R subtests requiring H-E coordination
  – Comparable to children with nutritional deficiencies, high blood lead concentration, LBW, prematurity

• **Post-spectacle wear**:
  – VMI scores improved = to emmetropic controls
  – WPPSI-R also improved but not stat significant

*Roch-Levecq et al. Archives of Ophthalmology 2008;126;252-8*
Baltimore Reading and Eye Disease Study

• Second and third grade students at 12 Baltimore City public schools
• Baseline: hyperopia (≥ 1D) was associated with worse reading scores
How Free Eyeglasses Are Boosting Test Scores in Baltimore

Educators know that poor kids do worse in school. The solution might be as simple as helping them see the board.

By SARAH GAMARD | August 17, 2017
What About Accommodation?
Accommodation

- Accuracy
- Amplitude
- Stability
Accommodative Accuracy: MEM
Accommodative Accuracy as Function of Age

Tarczy-Hornoch et al., J AAPOS 2012;16:112-117
Accommodative Accuracy as Function of Refractive Error

Tarczy-Hornoch et al., J APOS 2012;16:112-117
Accommodation

Accuracy | Amplitude | Stability
Accommodation in Young Children

• Normal accommodative abilities
  • Southall (1937); 4000 children
  • Mean amplitude = 14 D for 8-year-old (range 12-16 D)
• So why would kids with 4 or 5D of hyperopia not accommodate well?

It’s not JUST the accommodation…
…it’s getting the accommodation without getting over-convergence
Subjective versus Objective Accommodative Amplitude: Preschool to Presbyopia

Heather A. Anderson* and Karla K. Stuebing†

Optom Vis Sci 2014:91:1290-1301

Subjective vs. Objective Accommodative Amplitude:
Subjective Push-up Amp
Objective Minus Lens Amp
Objective Push-up
Maximum Monocular Amplitude as Function of Age

Accommodation

- Accuracy
- Amplitude
- Stability
Accommodative Stability

Refractive Error (D)

4.1 year-old
+0.81 D SE

4.4 year-old
+4.18 D SE

Adapted from Roberts et al., Optom Vis Sci 2018; Vol 95(3)
Accommodative Variability

\[ r = 0.44, \ P < 0.001 \]

Adapted from Roberts et al., Optom Vis Sci 2018; Vol 95(3)
Bottom Line? Accommodation and Hyperopia

• Babies can accommodate as early as 3 months
• Accommodative accuracy at 3 months may be predictive of emmetropization
• Accommodative lag tends to increase with increasing amounts of uncorrected hyperopia
• It's not just accommodative amplitude – vergence may become a problem
• Accommodation is more variable with increasing amounts of uncorrected hyperopia
Goals of Refractive Correction for Hyperopia in Young Children?

- Improve visual acuity
- Improve binocular function
  - Eye alignment and stereopsis
- Prevent amblyopia and/or strabismus
- Treat amblyopia or strabismus
- Manage accommodative or vergence demands
- Reduce signs and symptoms
- Improve function at near
- Prevent visuocognitive, visuomotor, or early literacy deficits
Questions??

scotter@ketchum.edu

tawnar17@gmail.com